3 KW TOTEM–POLE PFC REFERENCE DESIGN

with CGD65D025SP2

USER GUIDE

CGD – UG2406

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Important Information

- **The CGD65D025SP2 device has been superseded. Please contact CGD for updated details on this TPPFC design and ICeGaN® products.**
- **Due to the above, the 3 kW TPPFC is now a virtual reference design. PCB files are available upon request, but no hardware can be sent.**

Safety Warning

The CGD totem–pole power factor correction (TPPFC) reference design PCB is for evaluation purposes only. It is not intended to be a finished product and does not include all protection features found in a commercial power supply.

DANGER: Do not touch the board when high voltages are applied. There are exposed locations of high voltage on the board when connected to a power source. Brief contact may result in serious injury or death. Allow all components to fully discharge before handling the board. This evaluation kit is designed for use by qualified, experienced engineers only. Appropriate safety measures must be put in place before use and the board should never be left unattended.

WARNING: Some components may become hot during operation and remain so afterwards. Operating voltages, currents and temperatures should be monitored closely throughout operation to prevent damage to the board.

CAUTION: This product contains parts susceptible to ESD (electrostatic discharge). ESD prevention procedures must be used while handling the board.

Operating Limits and Recommendations

Voltage, current and power limits

CGD has tested the board within the following ranges: input voltage range of 115-230 V_{AC} 47-63 Hz, output voltage 400 V, RMS input current 0-13.5 A. At 115V_{AC} the maximum output power allowed is 1500 W; At 230 V_{AC} the maximum output power allowed is 3000 W. This design is for demonstration purposes only and should not be used to power any loads other than an electronic load. Only trained professional using high voltage equipment should operate the board and appropriate safety precautions should be followed.

Heat dissipation

This is an open frame design. CGD makes no guarantee of the thermal performance.

Do not touch the circuit components until the components cool down after turning off. In full–load conditions, temperatures of certain circuit components like totem-pole PFC ICeGaN® devices, magnetics and MOSFETS could heat up beyond 80 °C after 20 minutes of operation, with ambient temperature of 25 °C. Therefore, it is recommended to use a thermal camera to monitor the circuit temperature during circuit operation and turn off the circuit if the temperatures rise above nominal operating temperatures.

Target Audience

This user guide, along with the reference design, is intended to be used only by experienced engineers and assumes a knowledge of necessary equipment to analyse the performance of the PCB. It is designed to enable SMPS engineers, design engineers and technicians involved in the development of a power electronics system to assess the performance of CGD ICeGaN devices.

Technical Support

For support, please contact CGD at info@camgandevices.com.

Revision History

Revision Number	Comments	Engineer(s)	Date
1.0	Initial Issue	CT	09/10/2024
2.0	Added errata due to DHDFN package being EOL	DSM	15/04/2026

Contents

1 Introduction

This user guide provides essential information about the continuous conduction mode (CCM) bridgeless TPPFC reference design from CGD, a 3 kW offline power converter, and serves as a manual to understand and operate the board. While the board is capable of operating at a range of voltages from 90 V_{AC} to 265 V_{AC}, it was specifically designed and optimised for operation at two standard voltages: 115 V_{AC} and 230 $V_{AC,}$ the maximum input current should not exceed 13.5 A for safe and optimal performance. This means 3 kW is the maximum output power at 230 V_{AC} and 1.5 kW is the maximum output power at 115 V_{AC}. Always ensure to operate within these specified limits. Table 1 lists the main specifications and maximum operating limits of this evaluation board.

The reference design allows users to evaluate the performance of CGD65D025SP2 (ICeGaN, P2 series). It is a 650-V 25-mΩ enhancement–mode GaN (eMode-GaN) dual-side cooled device with proprietary ICeGaN technology. ICeGaN is CGD's gate technology featuring a high threshold which enhances noise immunity, and broad gate voltage window compatible with gate-driver ICs designed for MOSFETs.

Table 1 – Key specifications

Description	Value	Unit
Input ac line voltage range	90 – 264	V
Input ac line frequency range	47 – 63	Hz
Output voltage	400	V
Maximum input current at 230 V_{AC}	13.5	A
Maximum output continuous power a 230 V_{AC}	3000	W
Maximum output continuous power at 115 V_{AC}	1500	W
Maximum peak–to–peak output ripple	< 5	%
Power Factor (PF) (load range: 10% -100%)	> 0.95	
THD compliance	IEC 61000–3–2	
Conducted EMC compliance	CISPR 32 Class A	
Peak efficiency	99	%
Switching Frequency	65	kHz
Board dimensions (with daughterboard inserted)	70 x 252 x 40	mm

The CCM TPPFC controller used in this design is the NC1681. This controller is well supported with technical documentation and design tools. The design equations for the TPPFC are well known and out of the scope of this user guide.

The contents of this user guide include key specifications, PCB description, test set up, test results, key waveforms, circuit schematics, PCB layout, and bill of materials (BOM) of the CGD 3 kW TPPFC reference design.

2 Basic Totem–pole PFC Operation

Figure 1 and Figure 2 illustrate the basic operation of the TPPFC topology using a boost PFC analogy to easily understand the switching sequence of the four power devices; the two ICeGaNs on the fast leg and the two MOSFETs on the slow leg.

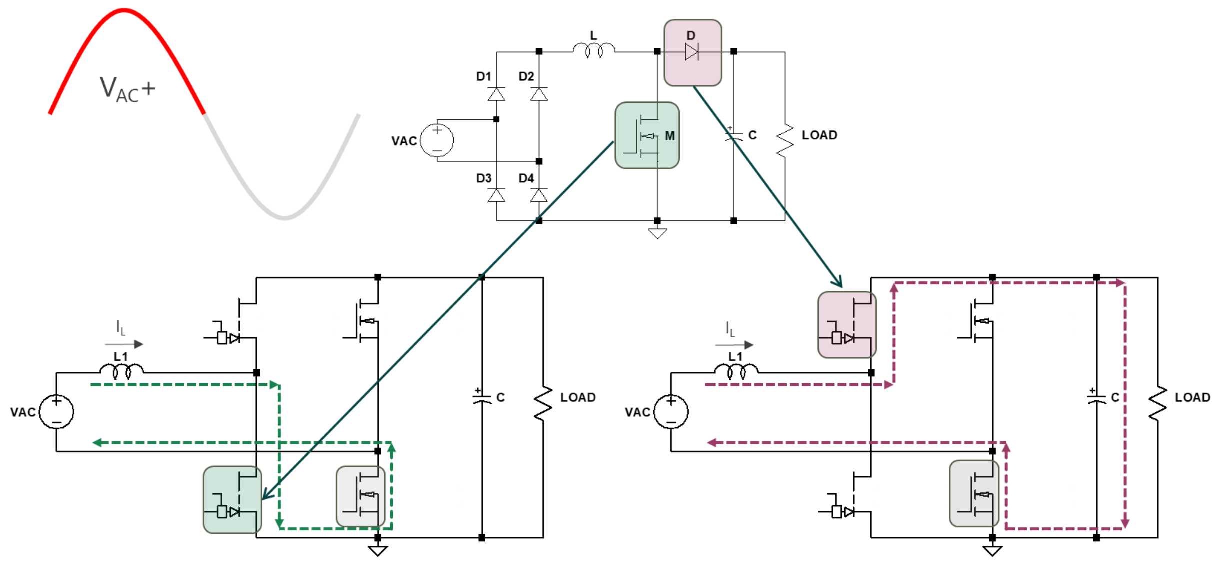


Figure 1 – TPPFC operation with Boost PFC analogy during the positive ac cycle

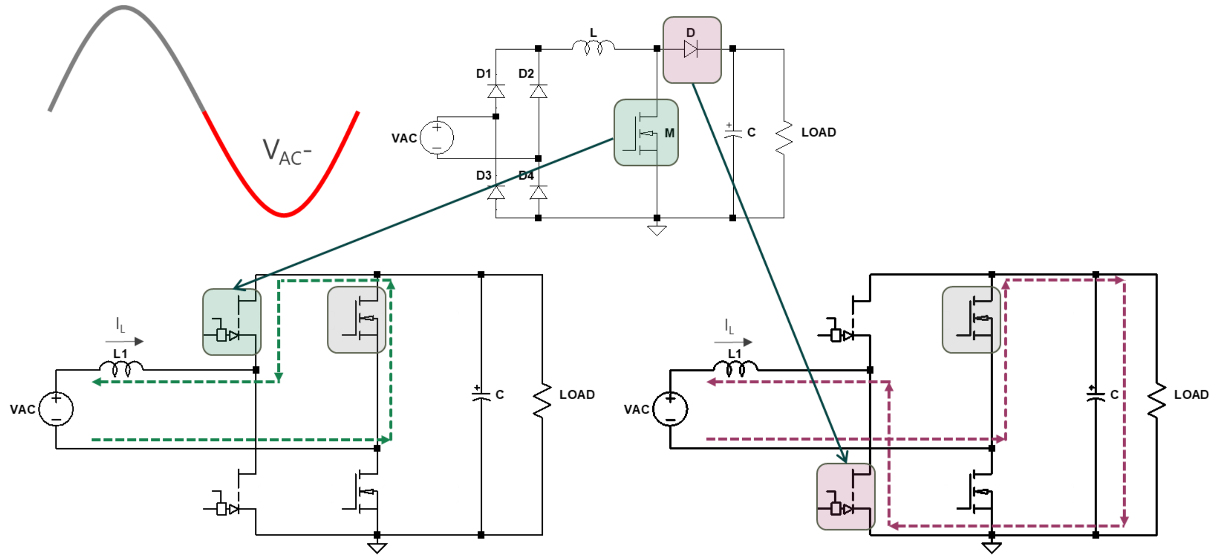


Figure 2 – TPPFC operation with Boost PFC analogy during the negative ac cycle

3 System Description

The CGD 3 kW TPPFC is not only designed for high efficiency applications like those requiring to meet 80+ Titanium, but it also showcases the innovative dual–side cooled DHDFN package. DHDFN stands for dual heat-spreader dual flat no leads. This package is capable of dissipating power effectively while maintaining a compact form factor. It achieves this with the help of a small heatsink mounted on the top side of the two ICeGaN devices. The heatsink is air-cooled by small-footprint fan placed in the mainboard. This design promotes high efficiency and efficient cooling, ensuring the devices remain cool even under high power operations.
This board was designed with an open-frame construction. The thermal solution and the mechanical dimensions closely mirror what would be used in a real-world application, demonstrating a practical approach for volume and power density. This design could be used to develop the input stage of a common redundant power supply (CRPS) server power supply.

The board maintains a high Power-Factor (PF) and low Total Harmonic Distortion (THD), even at light loads, and passed EMC compliance ensuring it meets industry standards. This focus on thermal management, efficiency, and compliance, along with a design strategy that ensures a balance between performance, feasibility, and market expectations; and makes CGD's DHDFN 25 mΩ ICeGaN as a distinctive contender for TTPFC topologies to deliver a robust and reliable solution across a range of applications.

The TPPFC slow leg employs N-Channel 10-mΩ 650 V MOSFETs to minimise the conduction losses. The Si8273ABD-IS1, a standard MOSFET 650 V half-bridge isolated gate–driver IC has been selected to drive these MOSFETS.

The fast–leg half–bridge is implemented on a daughterboard and uses two CGD65D025SP2 ICeGaN devices driven by the same gate–driver IC (Si8273ABD-IS1) used for the slow leg MOSFETs. ICeGaN devices have an internal Miller Clamp for turn off, thus only an external gate resistor is necessary for each ICeGaN. CGD's ICeGaN simplifies the driving of the GaN HEMTs; there is no need for negative gate drive or specific GaN driver which reduces complexity and part count. Moreover, ICeGaN provides significantly stronger gate robustness against gate overvoltage than discrete GaN.

The CCM PFC topology operates with fixed 65 kHz frequency. The PFC choke is a 370 µH inductor. The bulk capacitor consists of fourteen 120 µF / 450 V electrolytic capacitors in parallel. With such value the low frequency output voltage ripple (100 Hz /120 Hz) is less than 5% peak–to–peak and ensures an excellent hold–up characteristic.

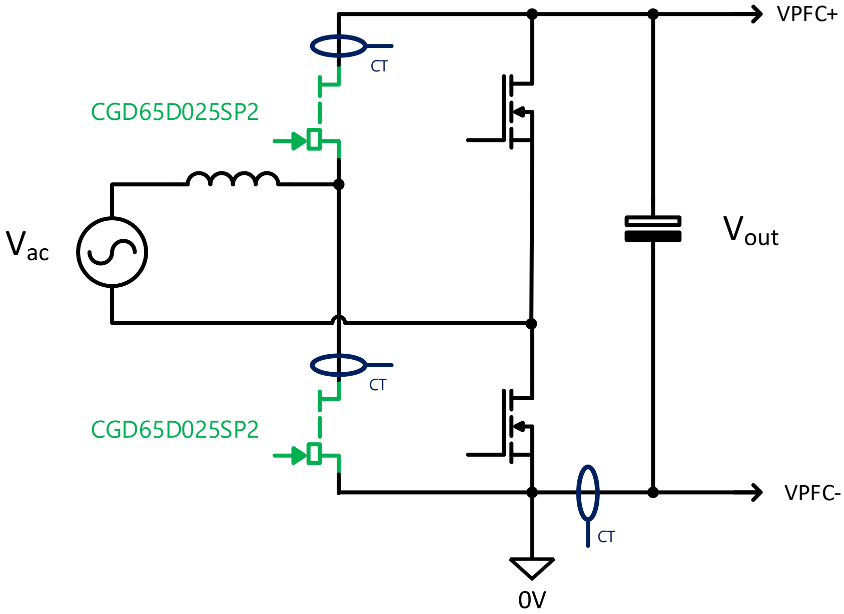


Figure 3 – CGD 3 kW TPPFC functional schematic

The TPPFC controller, the NCP1681, requires sensing the output current and the ICeGaN current during the t_{on} periods. Therefore, the current sense is implemented using three current transformers (CT); one of them is placed between the negative terminal of the electrolytic bulk capacitor and the source of the low-side MOSFET and ICeGaN devices, and the other two, connected to the drain terminal of each ICeGaN device, see Figure 3. Preventing the CT terminals from shorting is extremely important. Otherwise, this could lead to hazardous conditions or even damage the unit. Special attention should be given to the placement of the oscilloscope ground probe connections to avoid indirect short–circuiting the 0V and VPFC– nodes. For more details check the NCP1681 datasheet.

4 Board Description

The reference design consists of four PCBs, a mainboard and three daughterboards: a control daughterboard, an auxiliary voltage daughterboard, and the HF daughterboard, which is the high-frequency leg of the totem-pole PFC. The HF daughterboard includes mainly the high-frequency half-bridge's ICeGaN devices, with top-side heatsink, along with their gate-driver IC.

4.1 Full board assembly

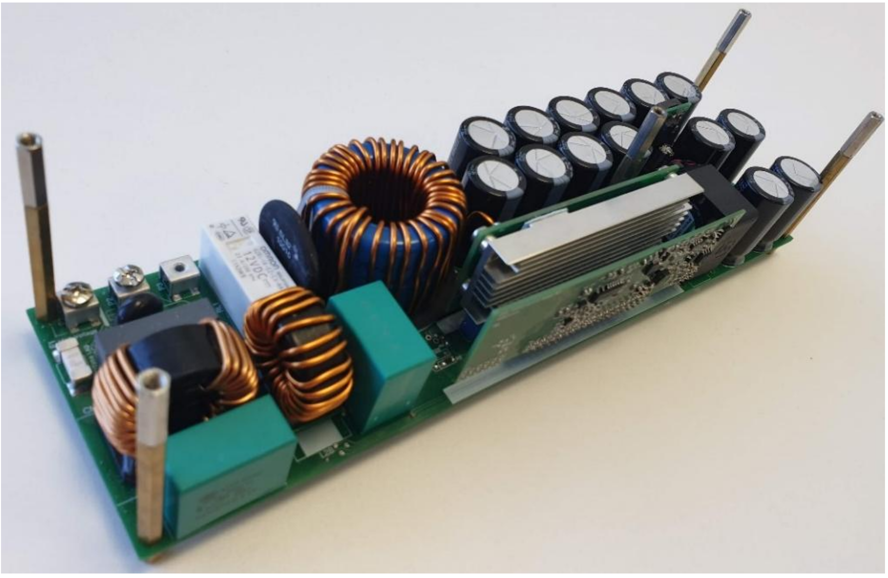


Figure 4 – CGD 3 kW TPPFC unit assembled

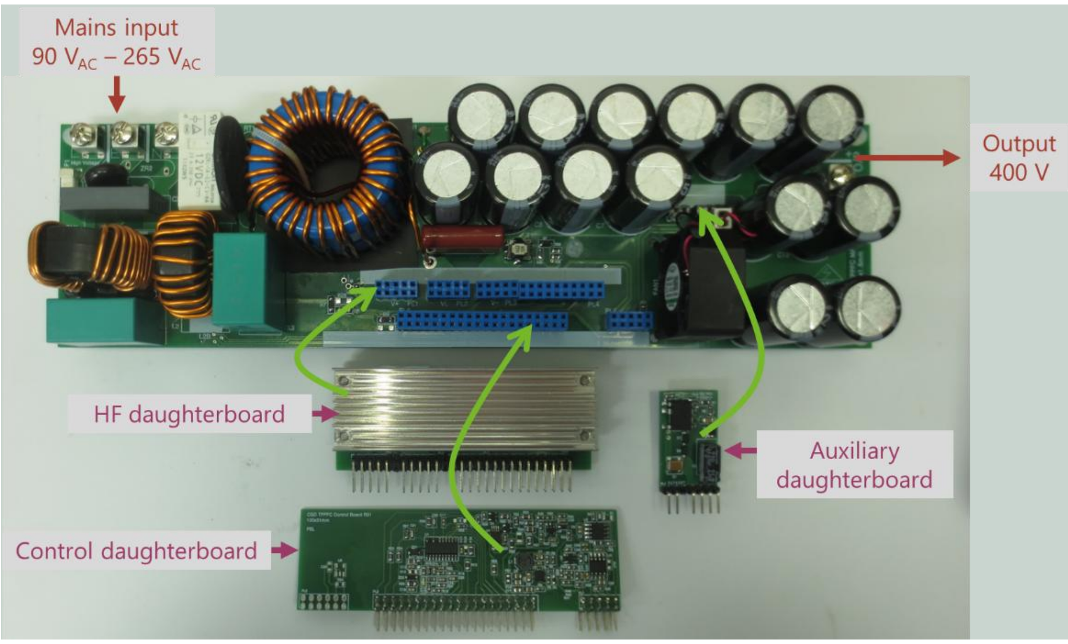


Figure 5 – Mainboard & daughterboards top view and connector positions

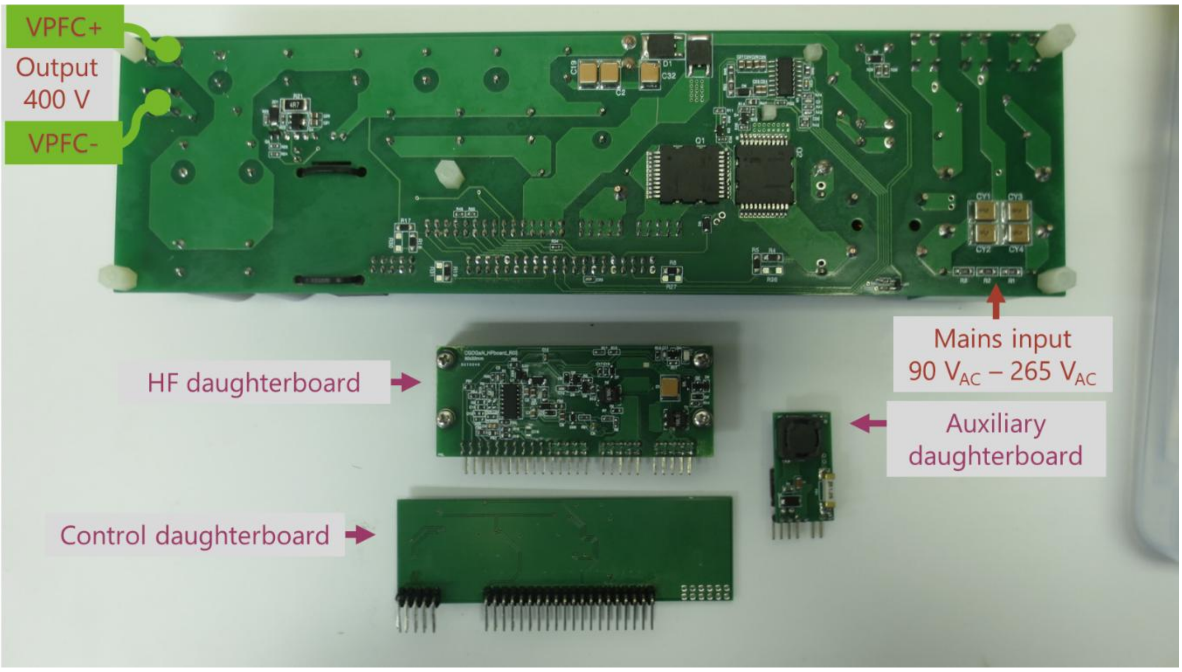
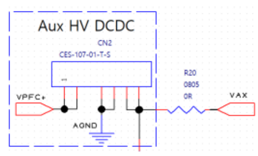
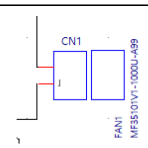
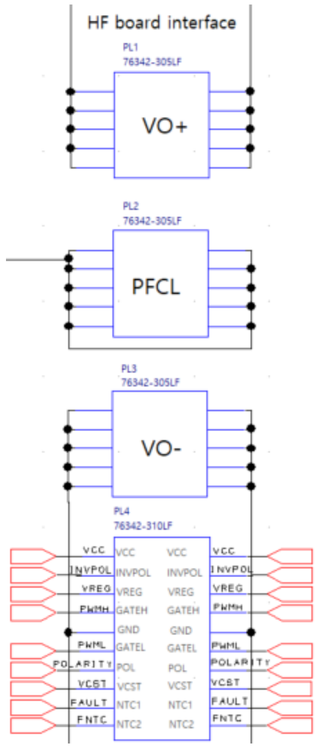
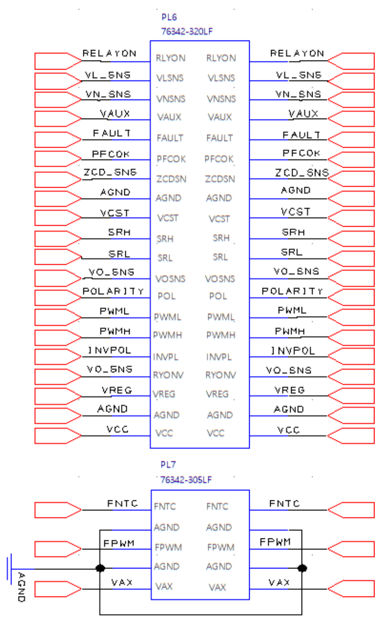


Figure 6 – Mainboard & daughterboards bottom view

Figure 4, Figure 5 and Figure 6 show different views of the four boards, the input and output connectors and the correct position of the three daughterboards plugged in the mainboard. Table 2 lists all the connectors and pins on the mainboard.

Table 2 – Mainboard I/O connectors

Mainboard Connectors	Function	Pinout	Description
P1/P2/P3	AC Input Voltage	P1. L (AC Line) P2. E (Earth) P3. N (AC Neutral)	90 V_{AC} / 265 V_{AC} input voltage
P4/P5	DC Output Voltage	P5. VPFC+ P4. VPFC–	400 V_{DC} output voltage
CN2	Auxiliary daughterboard Interface	1. VPFC+ 2. VPFC+ 3. Not connected 4. AGND 5. AGND 6. VACDC	
CN1	Fan Connector	1. AGND 2. +12V	

Mainboard Connectors	Function	Pinout	Description
PL1/PL2/PL3/PL4	HF daughterboard Interface	PL1. VO+ PL1. VO+ PL1. VO+ PL1. VO+ PL2. PFCL PL2. PFCL PL2. PFCL PL2. PFCL PL3. VO– PL3. VO– PL3. VO– PL3. VO– PL4.VCC PL4.INVPOL PL4.VREG PL4.PWMH PL4.GND PL4.PWML PL4.POLARITY PL4.VCST PL4.FAULT PL4.FNTC	
PL6/PL7	Control daughterboard Interface	PL6. RELEYON PL6. VL_SNS PL6. VN_SNS PL6. VAUX PL6. FAULT PL6. PFCOK PL6. ZCD_SNS PL6. AGND PL6. VCST PL6. SRH PL6. SRL PL6. VO_SNS PL6. POLARITY PL6. PWL PL6. PWMLH PL6. INVPOL PL6. RYONV PL6. VREG PL6. AGND PL6. VCC PL7. FNTC PL7. AGND PL7. PWM PL7. AGND PL7. VAX	

4.2 Mainboard

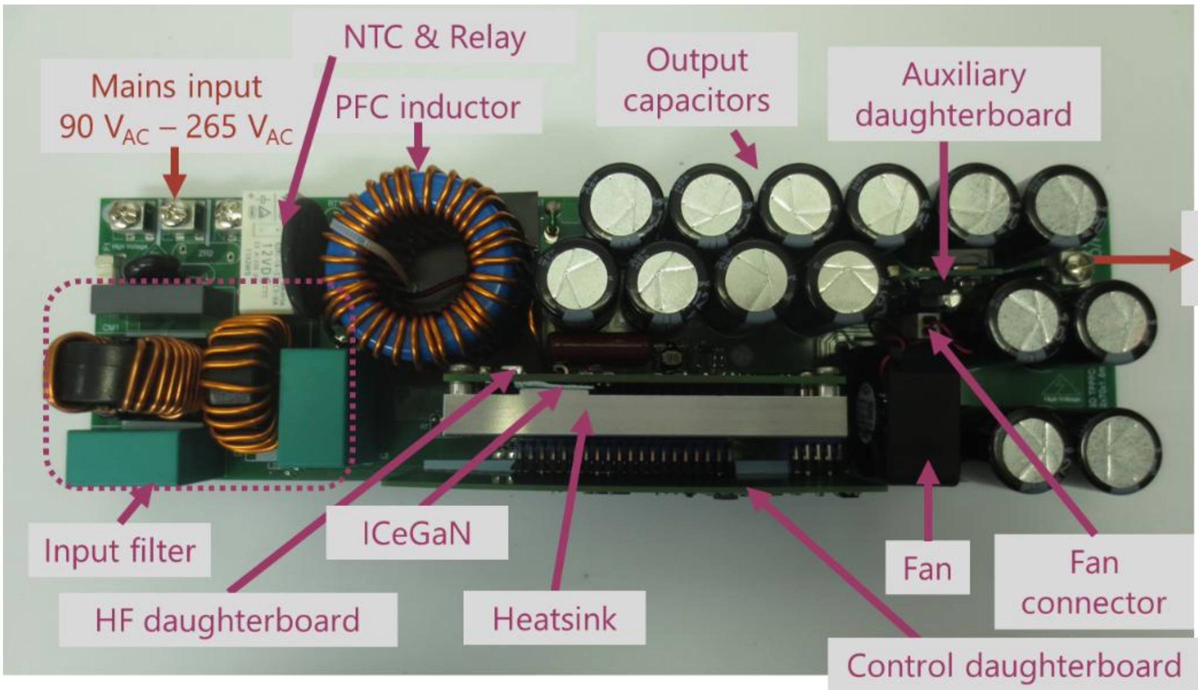


Figure 7 – Top view of fully assembled unit

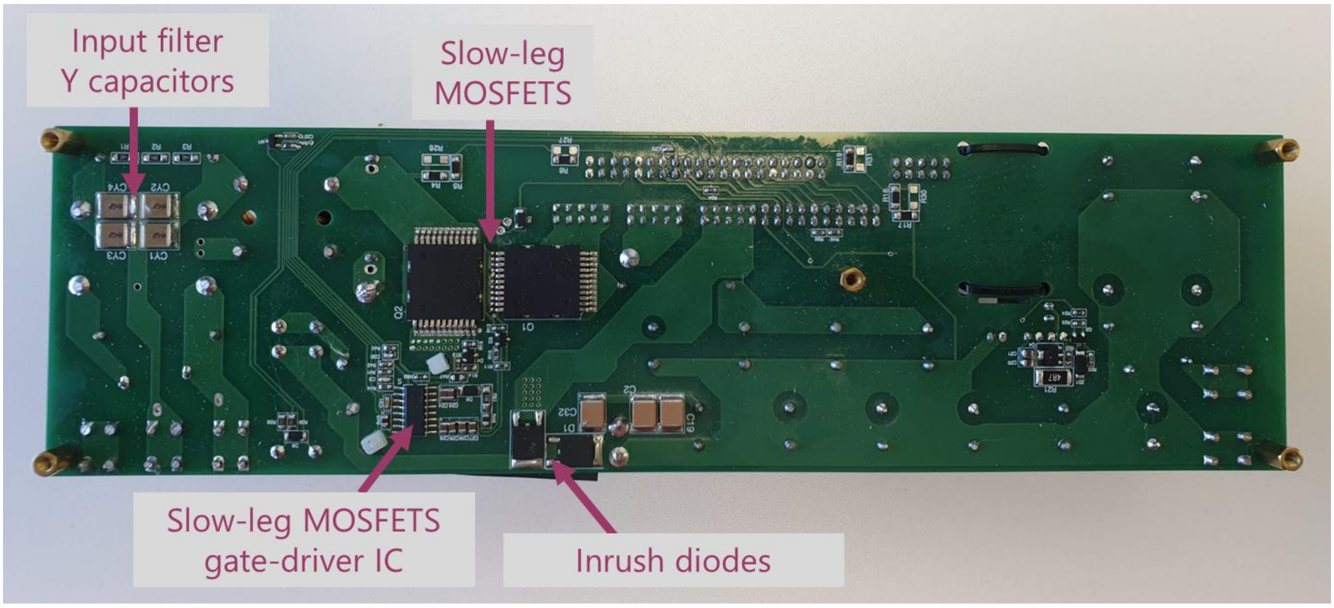


Figure 8 – Mainboard bottom view

4.3 ICeGaN fast-leg half-bridge daughterboard

The HF board includes the ICeGaN devices, the half-bridge gate driver IC, current transformers, and the heatsink which is mounted on the top side of the ICeGaN. Figure 9 shows the daughterboard with the heatsink dismounted to see the ICeGaN devices and two NTCs next to them for over temperature protection (OTP). PFCL node is the HB midpoint, VO– goes to the 0-V reference and VO+ is connected to the 400-V output; Connectors PL1/PL2/PL3/PL4 of this daughterboard must be connected to PL1/PL2/PL3/PL4 mainboard's connector, see Table 2.

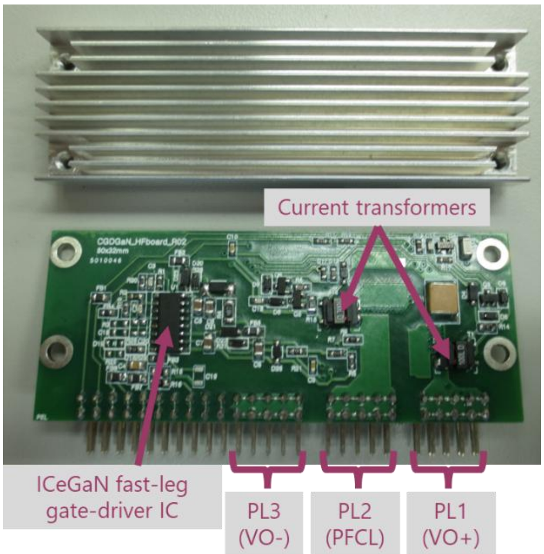
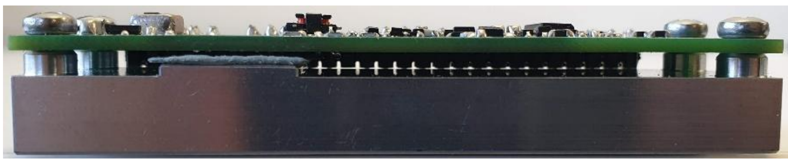


Figure 9 – HF daughterboard. Top side (left) and bottom side (right) views with the heatsink dismounted

Figure 10 shows the HF daughterboard with the heatsink mounted using M3 screws and the thermal interface material (TIM). The TIM part number GapPad 5000S35 conductivity = 5 W/(m•K), thickness = 0.5 mm.
The PCB thickness of this HF daughterboard is 1.6 mm, with 2 oz copper thickness. A thinner PCB is not recommended as it could bend, leading to poor thermal connection hence an increase in the operating temperature of the ICeGaN devices.



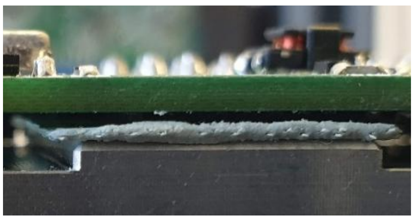


Figure 10 – HF daughterboard with heatsink mounted and detail of ICeGaN thermal connection with the TIM and heatsink

4.4 Control daughterboard

The control board includes the TPPFC controller IC, the low-voltage supply management circuitry, and an LED located near the controller IC, see Figure 11; When the LED is ON, it indicates the TPPFC is running and regulating correctly at 400 V. All the components in this daughterboard are in the top layer of the board and this top layer faces the outside of the unit so the LED is easily visible. The control daughterboard is positioned close to the HF daughterboard to ensure minimal electrical interference. Additionally, it is strategically parallel to the HF daughterboard to direct the fan-generated airflow towards the heatsink, enhancing cooling efficiency, This daughterboard must be connected to PL6/PL7 mainboard's connector. Control daughterboard's PL1 goes to mainboard's PL6, and control daughterboard's PL2 goes to mainboard's PL7. PL3 is left unconnected.

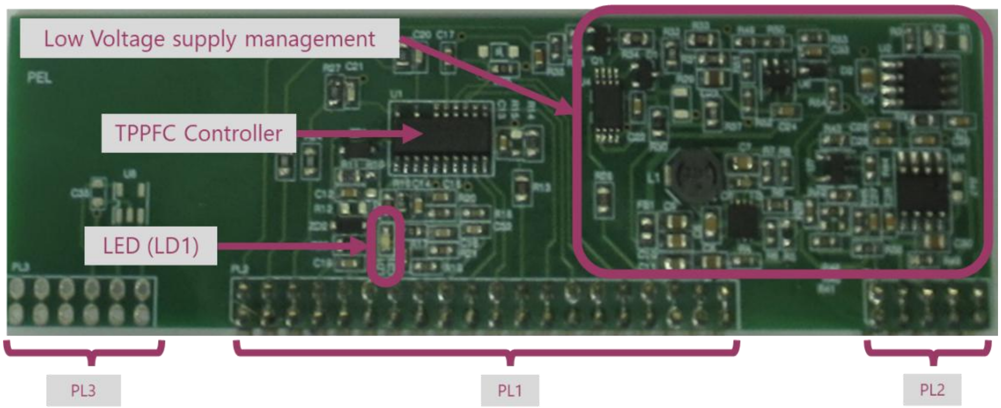


Figure 11 – control daughterboard. Top side view

4.5 Auxiliary daughterboard

The auxiliary daughterboard features a low-power buck converter to power the low voltage rail required for TPPFC control. Its input is connected to the 400-V output voltage rail, and it generates approximately 13 V in the output. Figure 12 shows the top and bottom views of the daughterboard and its main components plus the connector description. This board must be connected to CN2 mainboard's connector, see Table 2.

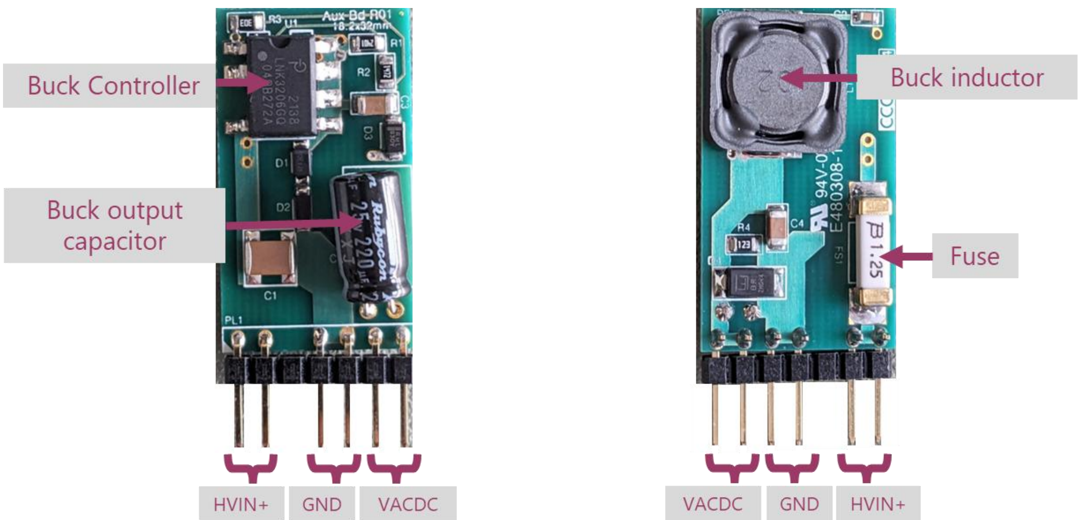


Figure 12 – Auxiliary daughterboard. Top side (left) and bottom side (right) views

5 Using the Board

5.1 Test procedure

Below are some important points to run the board correctly and safely:

1. Daughterboards must be inserted in the right position. See previous section 4
2. The 230 V_{AC} / 50 Hz or 115 V_{AC} / 60 Hz ac input voltage must be provided on P1 and P3. P2 is the earth connection, and it can be left floating if the test engineer considers so. See Table 2.
3. P4 and P5 are the output voltage connectors that should be connected to an eLoad or a resistive load. It is good practice to monitor the voltage across these pins: in steady state operation this voltage is 400 V. See Table 2. P5 (VPFC+) is positive with respect to P4 (VPFC-).
4. WARNING: T1 is a current transformer to measure the output current; it physically separates AGND and VPFC- nodes as illustrated in Figure 3. AGND is considered the 0-V reference and VPFC- corresponds to the negative terminal of the electrolytic capacitor in the output. Care must be taken to avoid shorting the T1 involuntary with the test equipment. For example, the ground leads of an Earth-connected oscilloscope probe must not be simultaneously connected to both GND and VOUT_RTN. This is particularly important if the user wants to measure the output voltage and other signals at the same time with the oscilloscope. A differential voltage probe can be used to monitor the output voltage to avoid shorting the T1.
5. There is no need for external low voltage rail.
6. There is no need for additional external fan.
7. The board was designed to operate at room temperature between 20 ºC and 30 ºC, and it has not been tested outside this temperature range.
8. WARNING: Before turning on, ensure the load connected to the unit is below 10% of full load operation. The maximum load connected to the evaluation board at start-up must be below 150 W for 115 V_{AC} or 300 W for 230 V_{AC}. Typically, in a typical 2-stage converter application the downstream converter connected to the TPPFC does not start until the TPPFC output voltage reaches a voltage level typically higher than 300 V.
9. The evaluation board includes an LED located in the control board. When the LED is ON, it indicates the TPPFC is running and regulating correctly at 400 V.
10. When the input voltage is turned off, it's crucial to pay special attention to the output voltage. You should wait until the output capacitor is fully discharged before proceeding. This precaution helps prevent any residual voltage from causing unintended effects or safety hazards.

5.2 Test set-up arrangement

The bench test set-up used to obtain results presented in the next section, is described below:

- A 2-channel power analyser was used for efficiency, power factor and THD measurements. Power analyser's channel 1 was attached to the input to measure input power, power factor and THD and channel 2 was connected to the output to measure output power. Figure 13 illustrates how the test-set up was arranged. The power analysers' voltmeter in the input was connected directly to connectors P1 (L) and P3 (N). The power analyser's voltmeter in the output was connected directly to connectors P5 (VPFC+) and P4 (VPFC-).

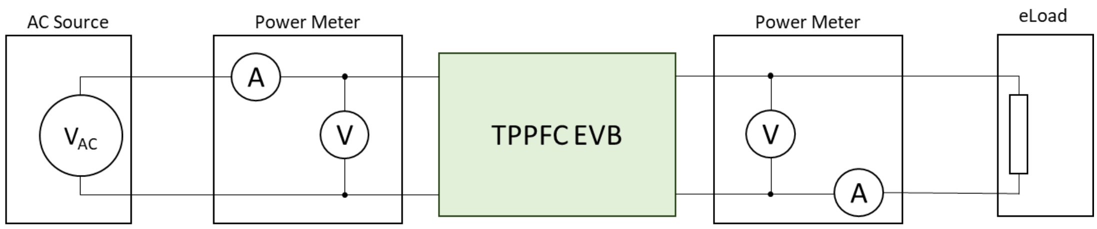


Figure 13 – Test set–up for efficiency measurements

Table 3 – List of equipment use for efficiency, PF and THD

Equipment	Manufacturer	Part Number
AC Source	ITECH	IT7800
DC Electronic Load	ITECH	IT-M3804-800-16
2- Channel power analyser	GW Instek	GPM-8320

6 Test Results

All the results shown in this section have been obtained with the test set-up described in the previous section 5.2.

6.1 Efficiency

Table 4 – Efficiency results

CGD 3 kW TPPFC Efficiency										
115 V_{AC}	Output power (W)	151	303	453	605	756	907	1134	1361	1511
	Efficiency (%)	95.22	96.85	97.60	97.86	97.91	97.90	97.78	97.60	97.43
230 V_{AC}	Output power (W)	292	583	875	1166	1457	1752	2189	2626	2918
	Efficiency (%)	97.57	98.45	98.79	98.91	98.98	99.04	98.89	98.81	98.75

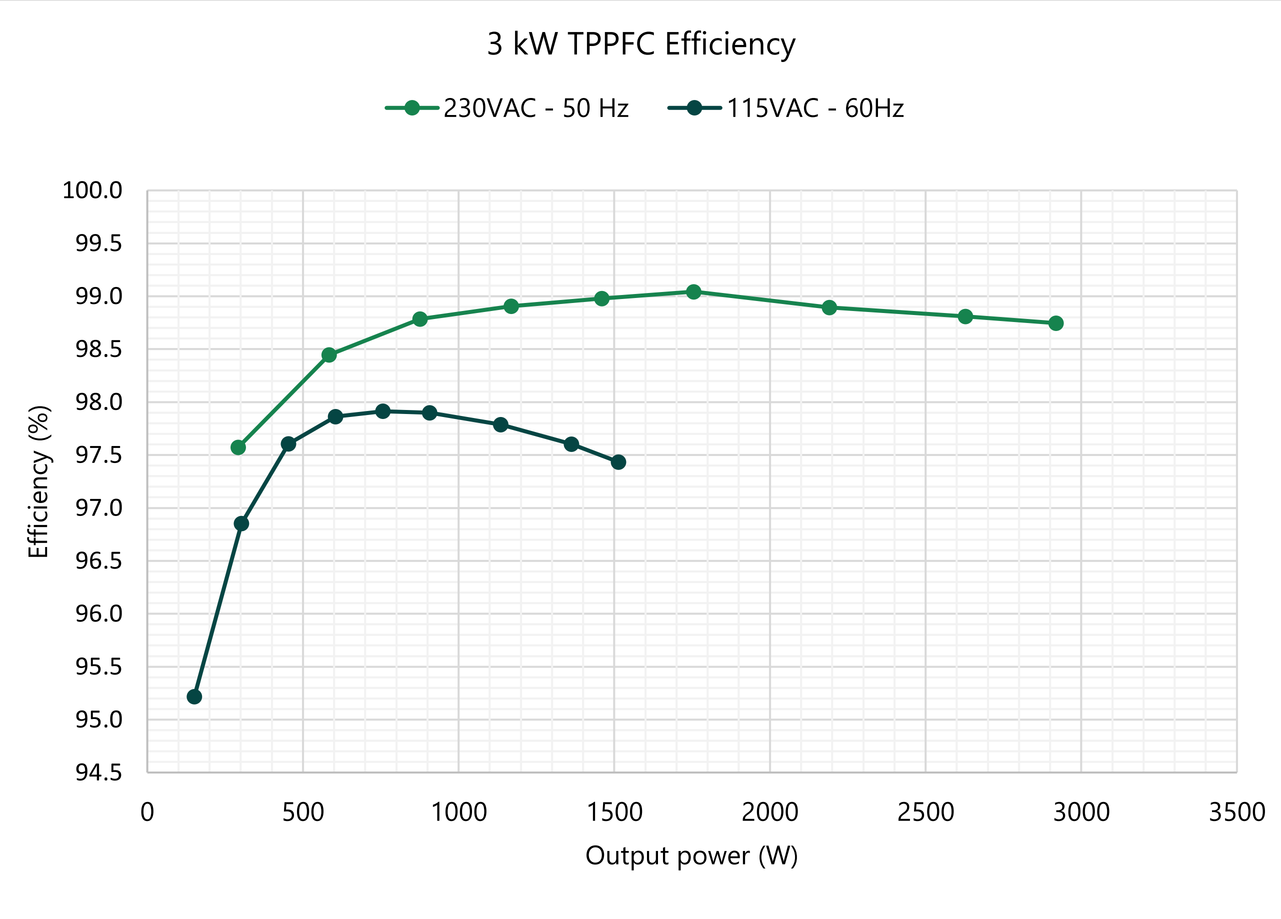


Figure 14 – Efficiency vs load at 115 V_{AC} and 230 V_{AC}

6.2 Power factor (PF)

Table 5 – Power factor results

CGD 3 kW TPPFC Power Factor										
115 V_{AC}	Output power (W)	151	303	453	605	756	907	1134	1361	1511
	Power Factor	0.979	0.993	0.996	0.997	0.998	0.998	0.998	0.998	0.998
230 V_{AC}	Output power (W)	292	583	875	1166	1457	1752	2189	2626	2918
	Power Factor	0.952	0.986	0.992	0.995	0.996	0.998	0.998	0.998	0.998

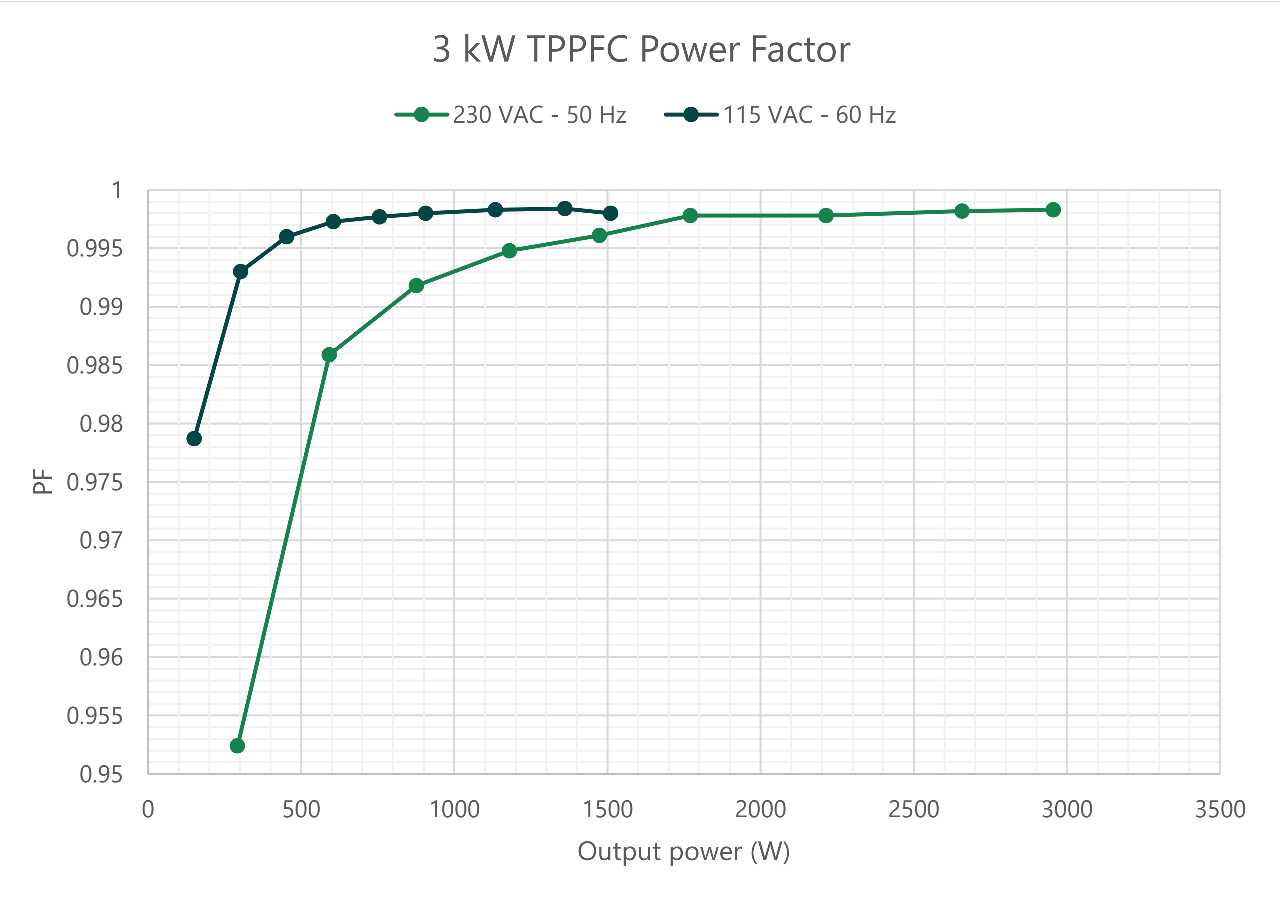


Figure 15 – Power factor vs load at 115 V_{AC} and 230 V_{AC}

6.3 Total harmonic distortion

Table 6 – THD results

CGD 3 kW TPPFC Total Harmonic Distortion										
115 V_{AC}	Output power (W)	151	303	453	605	756	907	1134	1361	1511
	THD (%)	8.88	4.76	4.53	4.68	4.88	4.86	4.77	4.77	5.25
230 V_{AC}	Output power (W)	292	583	875	1166	1457	1752	2189	2626	2918
	THD (%)	7.04	3.91	3.18	2.66	2.57	2.55	2.57	2.6	2.67

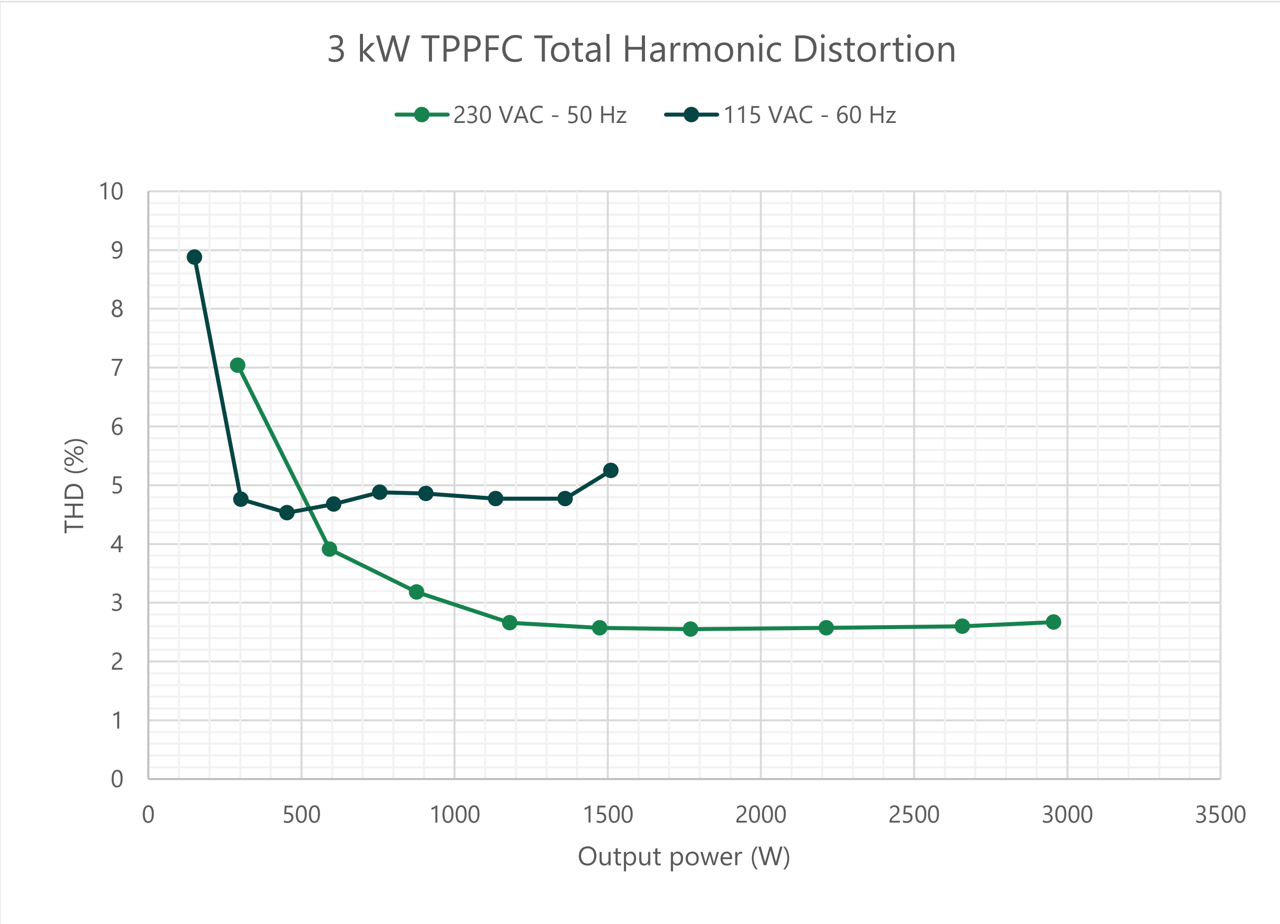


Figure 16 – THD vs load at 115 V_{AC} and 230 V_{AC}

6.4 Harmonic content at 230 V_{AC} / 3 kW

Table 7 – Harmonic content at 230 V_{AC} / 3 kW

Harmonic	Current	Limits for Class A (IEC61000–3–2:2014)	Harmonic	Current	Limits for Class A (IEC61000–3–2:2014)
Fundamental	13.14 A		21st	64 mA	107 mA
2nd	19.9 mA	1080 mA	22nd	5 mA	84 mA
3rd	184 mA	2300 mA	23rd	65 mA	98 mA
4th	11 mA	430 mA	24th	6 mA	77 mA
5th	56 mA	1140 mA	25th	65 mA	90 mA
6th	9 mA	300 mA	26th	6 mA	71 mA
7th	63 mA	770 mA	27th	65 mA	83 mA
8th	5 mA	230 mA	28th	5 mA	66 mA
9th	56.8 mA	400 mA	29th	66 mA	78 mA
10th	3.5 mA	184 mA	30th	6 mA	61 mA
11th	56 mA	330 mA	31st	65 mA	73 mA
12th	3 mA	153 mA	32nd	7 mA	58 mA
13th	62 mA	210 mA	33rd	61 mA	68 mA
14th	3 mA	131 mA	34th	6.7 mA	54 mA
15th	57 mA	150 mA	35th	57 mA	64 mA
16th	4 mA	115 mA	36th	5.5 mA	51 mA
17th	57 mA	132 mA	37th	55 mA	61 mA
18th	4 mA	102 mA	38th	5.8 mA	48 mA
19th	61 mA	118 mA	39th	50 mA	58 mA
20th	3.8 mA	92 mA	40th	7.4 mA	46 mA

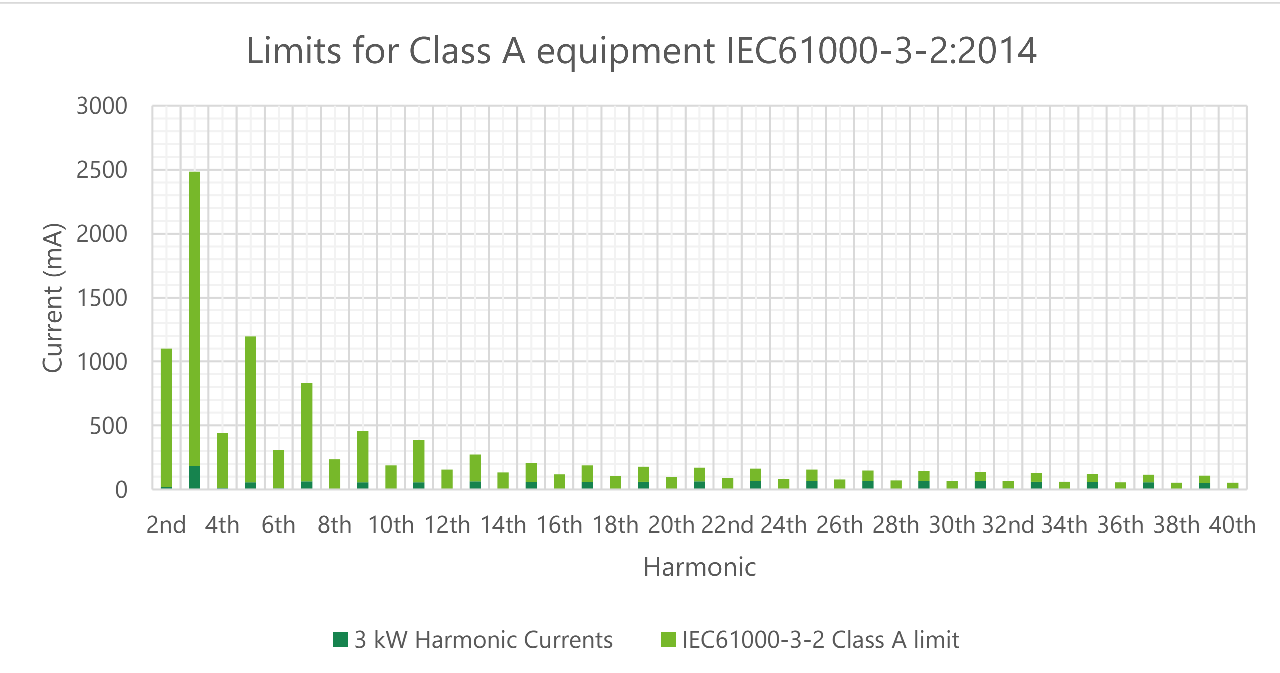


Figure 17 – Harmonic content at 230 V_{AC} / 3 kW

6.5 Conducted EMI

Test of conducted EMI were carried out in a EMC external laboratory. Figure 18 and Figure 19 are the results at 230 Vac / 3 kW and at 115 Vac / 1.5 kW. All the tests, even at lighter load, passed EN55022 Class A conducted emissions .

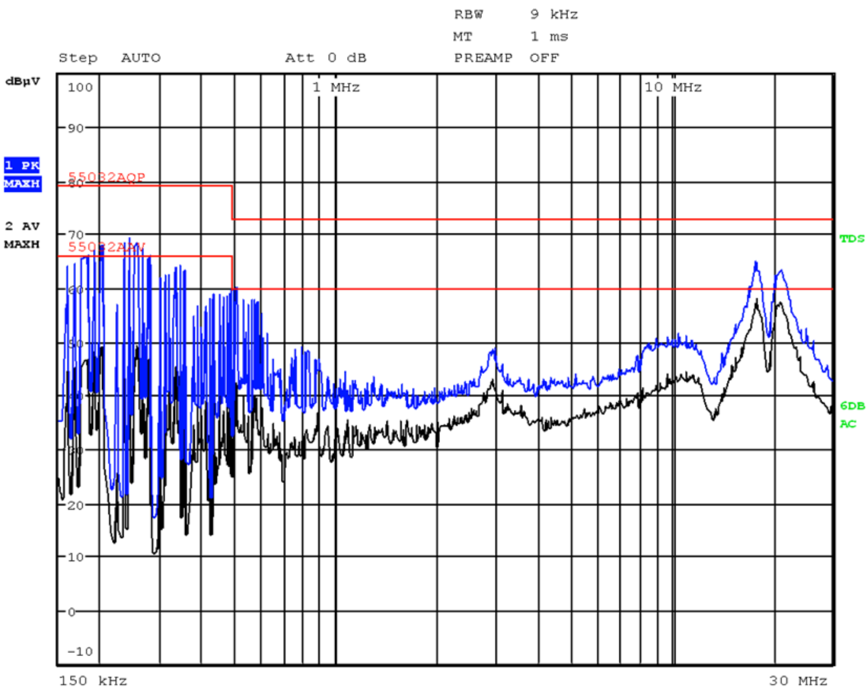


Figure 18 – EN55022 Class A conducted EMI at 230 V_{AC} / 3 kW

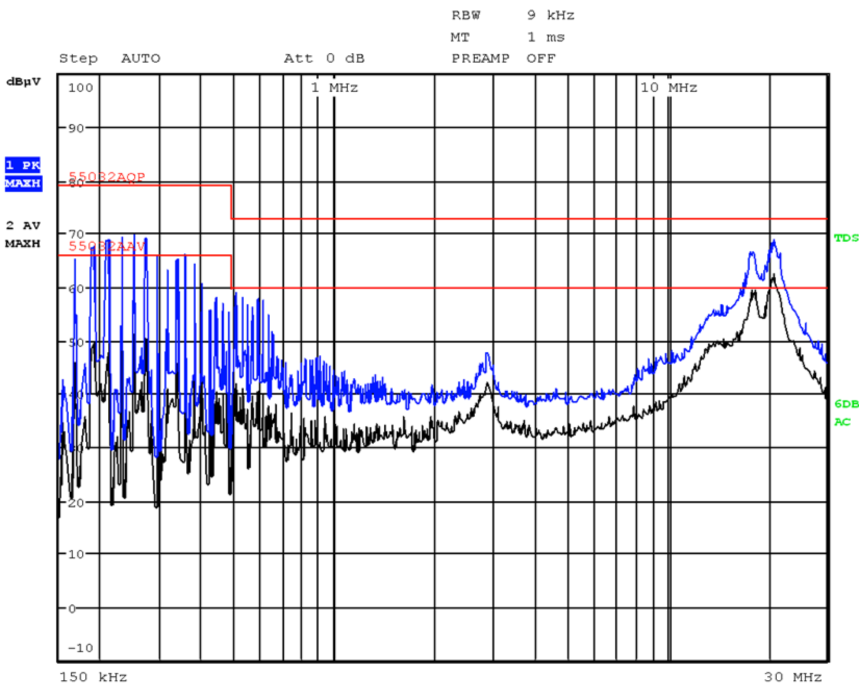


Figure 19 – EN55022 Class A conducted EMI at 115 V_{AC} / 1.5 kW

7 Design Considerations

In a CCM totem-pole PFC topology, low reverse recovery charge (Q_{RR}) silicon MOSFETs cannot be used in the fast leg. Instead, ICeGaN devices, which are GaN High Electron Mobility Transistor (HEMT) devices, offer a better choice to increase efficiency and reduce thermal stress. ICeGaN has no Q_{RR}, its gate charge (Q_G) is approximately 10 times lower than in a MOSFET with the same on-state resistance ($R_{DS(on)}$), and its output capacitance (C_{OSS}) is also lower and more linear. As a result, switching losses are significantly reduced when using ICeGaN in a CCM TPPFC. Moreover, GaN devices offer several advantages over silicon carbide (SiC) in TPPFC applications. In general, GaN's switching energy is more than 50% lower than that of SiC, which directly translates to lower losses in the TPPFC. These advantages not only enable designers to realise high power density, but also significantly reduce the cost and size of cooling components such as heatsinks and fans.

Unlike other GaN HEMT alternatives, ICeGaN is very simple to drive. There is no need for negative drive or any additional requirements to use a special gate driver. Therefore, a standard MOSFET HB isolated gate driver IC is employed in this EVB. Each ICeGaN only requires two small SMD components; a capacitor between VDD and Kelvin pins, and an external gate resistor as illustrated in Figure 20.

ICeGaN's internal logic supports a gate drive voltage range of 9 V to 20 V, allowing for a broad selection of gate–driver ICs. ICeGaN technology offers significantly improved noise immunity for gate voltage. This is achieved through its smart gate interface, which virtually eliminates typical weaknesses found in e-Mode GaN devices. Specifically, ICeGaN provides a higher noise-immune threshold, along with enhanced overvoltage robustness, dv/dt suppression, and ESD protection. A traditional MOSFET HB isolated gate driver is used instead of a dedicated GaN gate-driver IC. The external gate drive voltage is clamped to the optimum level on the internal gate of the ICeGaN device. This extends lifetime and reliability.

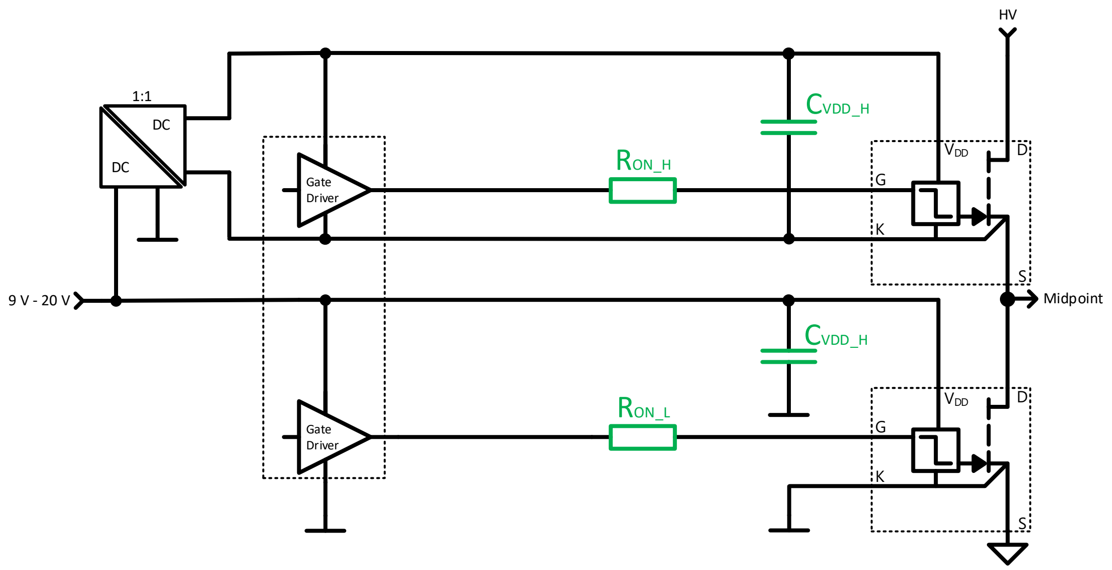


Figure 20 – External SMD components (in green) needed to drive ICeGaN in this EVB

The ICeGaN internal Miller Clamp is a major advantage over other GaN HEMTs. The internal Miller Clamp operates when V_{DD} is present, and clamps the internal gate voltage to zero volts. This means that the vast majority of the Miller current generated by the V_{DS} dv/dt does not flow through the external gate resistor. Therefore, parasitic inductance on the gate path is almost irrelevant at turn off, and undesirable spurious turn-on events are easily avoided. As a result, there is no need for negative gate drive, and there is no need for an external gate turn-off path. Thanks to the low gate charge, gate switching losses are negligible, and the gate driver does not require as much sink and source current capability compared with the use of a MOSFET. This EVB uses 20 Ω turn-on gate resistors in each ICeGaN device, and PCB layout on the gate paths are not as critical as with conventional GaN HEMT alternatives.

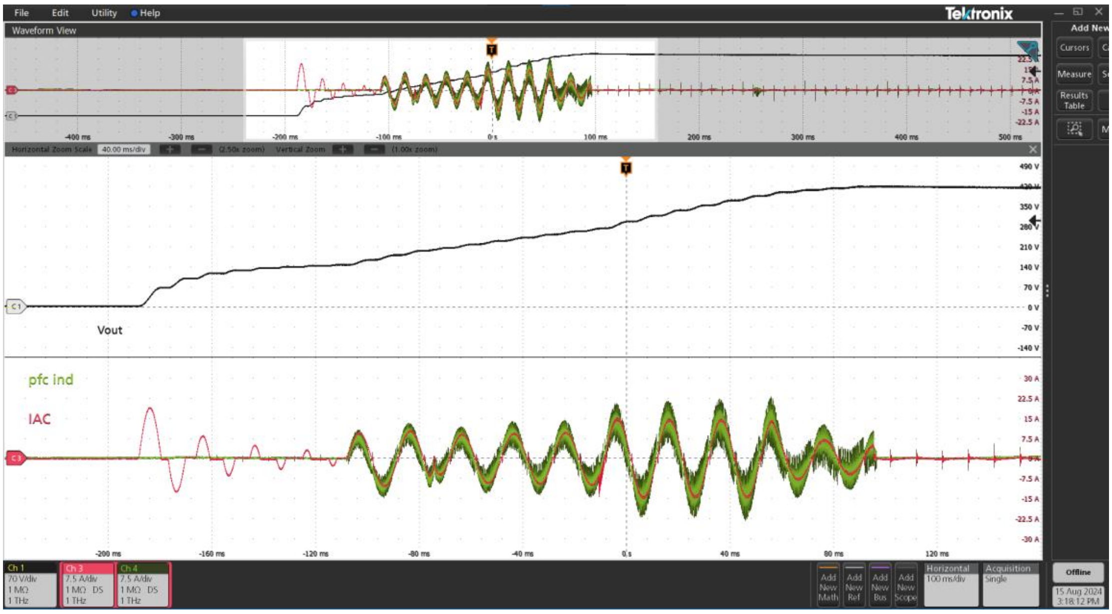
When the ICeGaN devices are not switching, the current flowing into their VDD pin is almost zero. The ICeGaN VDD pin only draws 1.7 mA when the gate pin voltage is in on state and typically 250 µA when the gate pin voltage is in off state; this feature was implemented to reduce power consumption under no-load conditions.

In summary, compared to Si & SiC MOSFETS or discrete GaN devices, DHDFN ICeGaN 25-mΩ device is an excellent choice for a CCM TPPFC for four main reasons:

1. ICeGaN is an IC based on eMode-GaN HEMT device. Lower switching losses than SiC, which boost efficiency and power density.
2. Driving ICeGaN devices is very simple and cost effective. A standard HB driver and four SMD components are required, See Figure 20.
3. Smart gate interface provides superior noise immunity, overvoltage robustness, dv/dt suppression, and ESD protection.
4. DHDFN is a thermally enhanced dual-side cooled SMD package. It offers flexible cooling options, allowing for top-side, bottom–side, or dual-side cooling. For more information about cooling see reference [1].

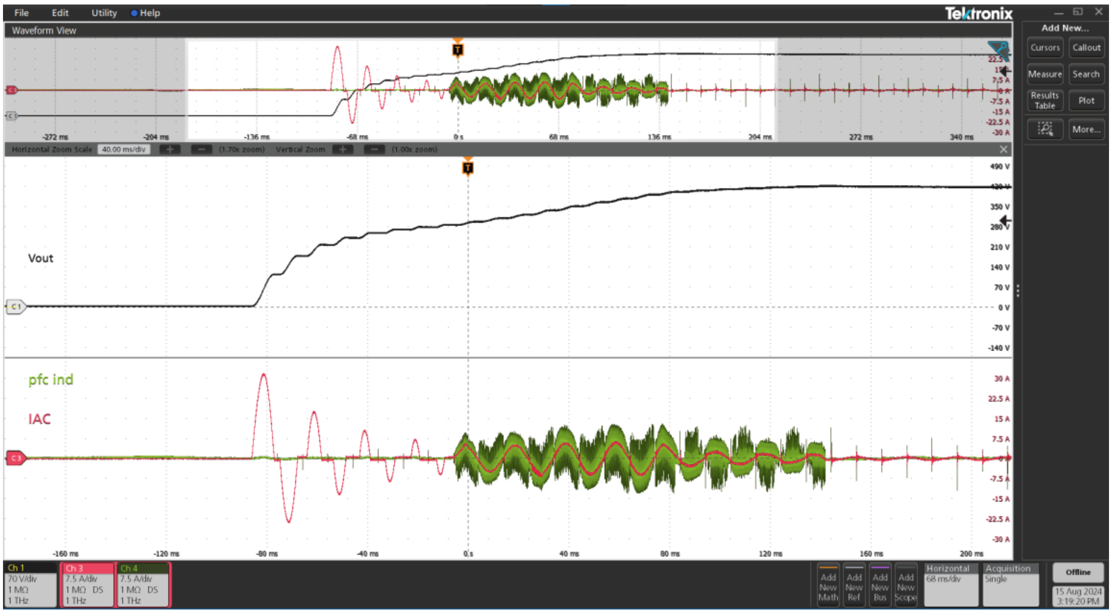
8 Waveforms

8.1 Start-up at no-load waveforms



CH 1 – Output voltage (70 V/div) CH 3 – Input current (7.5 A/div) CH 4 – PFC choke current (7.5 A/div)

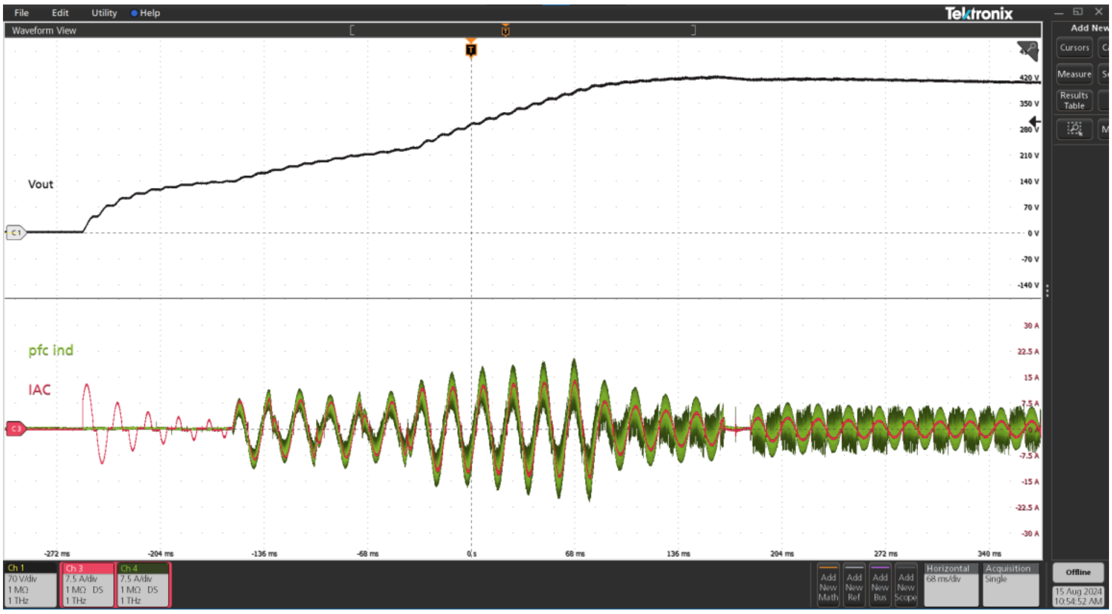
Figure 21 – Start-up at 115 V_{AC} / no load



CH 1 – Output voltage (70 V/div) CH 3 – Input current (7.5 A/div) CH 4 – PFC choke current (7.5 A/div)

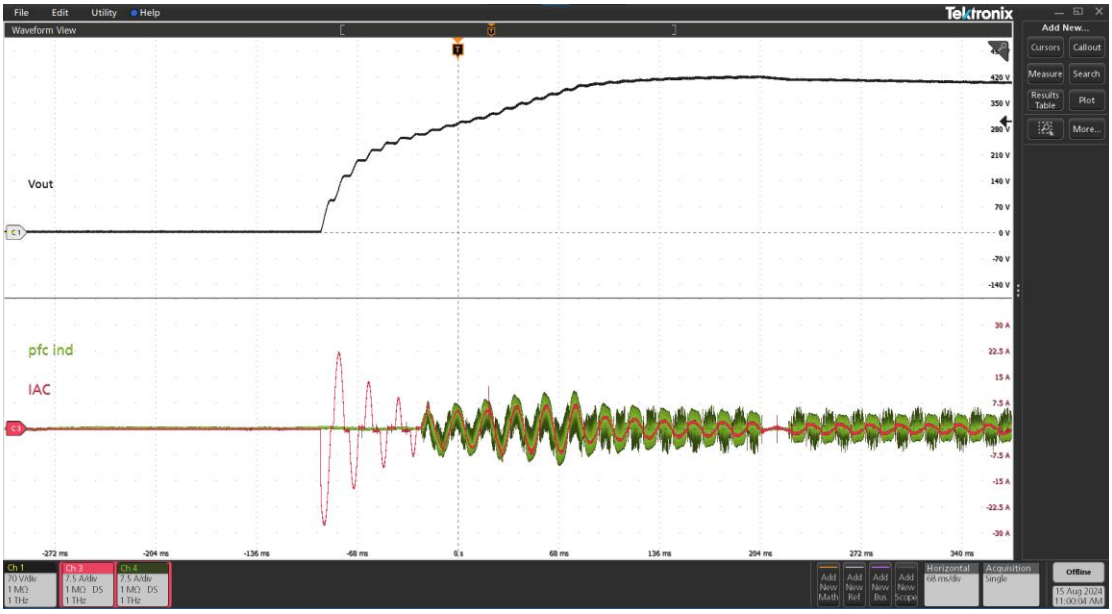
Figure 22 – Start-up at 230 V_{AC} / no load

8.2 Start-up at 10% load



CH 1 – Output voltage (70 V/div) CH 3 – Input current (7.5 A/div) CH 4 – PFC choke current (7.5 A/div)

Figure 23 – Start-up at 115 V_{AC} / 150 W



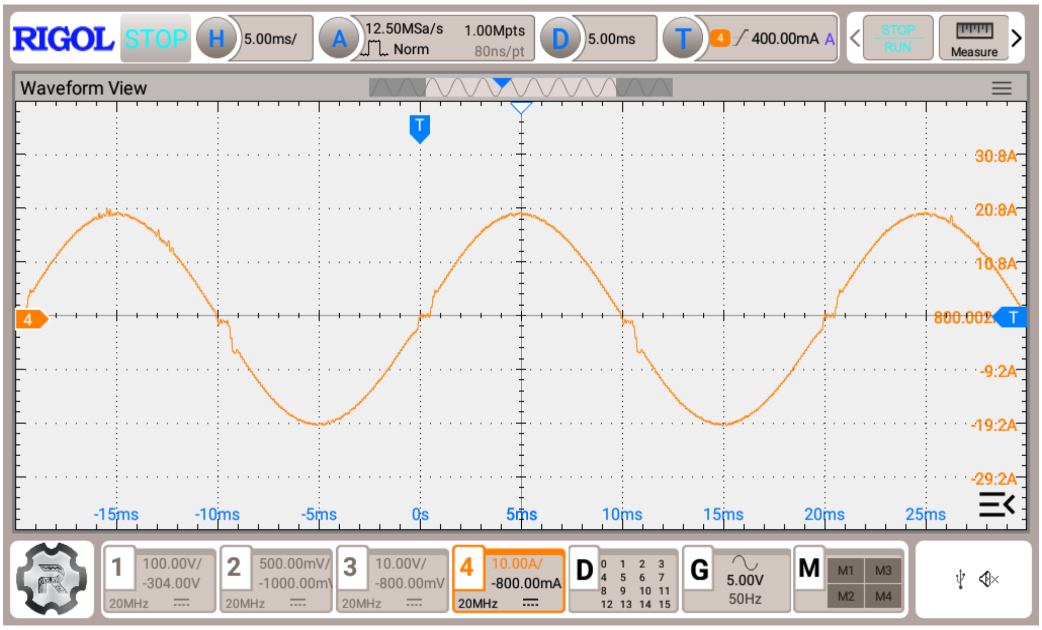
CH 1 – Output voltage (70 V/div) CH 3 – Input current (7.5 A/div) CH 4 – PFC choke current (7.5 A/div)

Figure 24 – Start-up at 230 V_{AC} / 300 W

8.3 Steady state waveforms

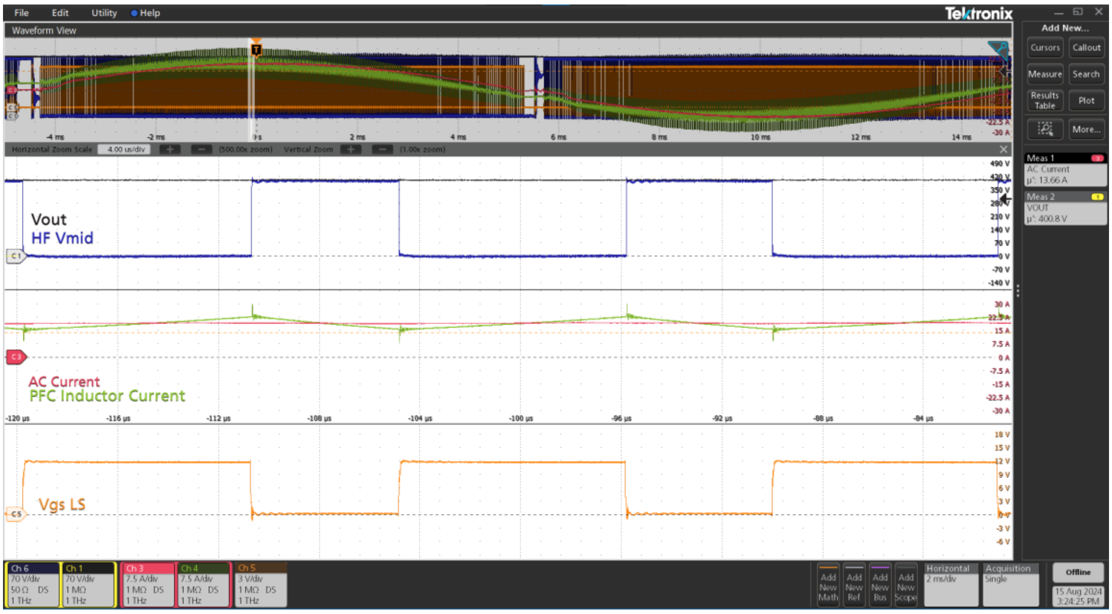
CH 4 – Input current (10 A/div)

Figure 25 – Input current at 115 V_{AC} / 1.5 kW



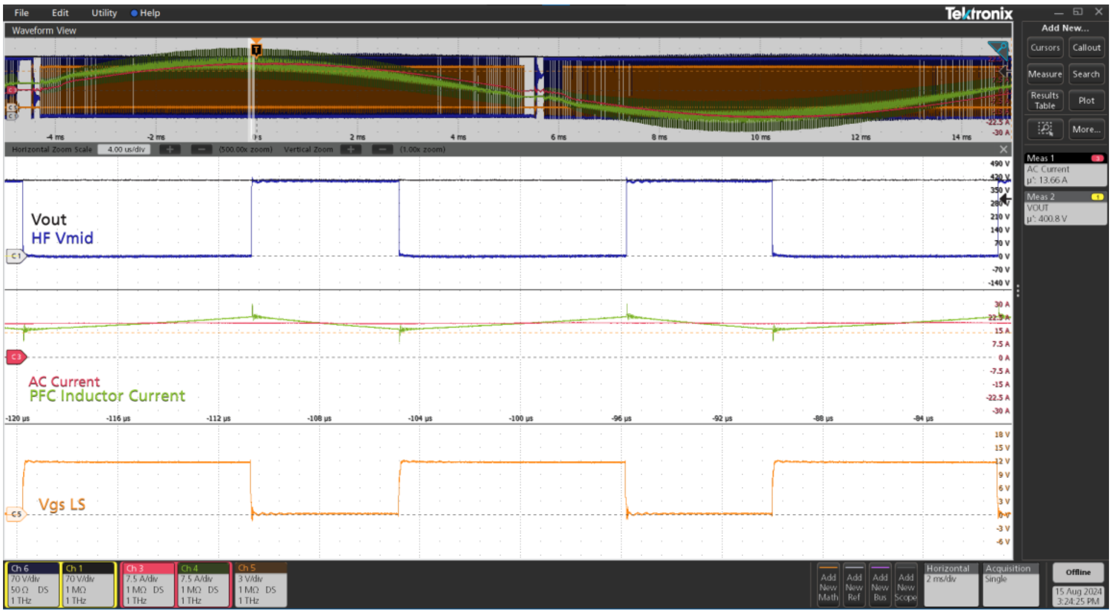
CH 4 – Input current (10 A/div)

Figure 26 – Input current at 230 V_{AC} / 3 kW



CH 1 – Output voltage (70 V/div) CH 3 – Input current (7.5 A/div) CH 4 – PFC choke current (7.5 A/div)
CH 5 – Low side gate voltage (3 V/div) CH 4 – PFC choke voltage (70 V/div)

Figure 27 – Main signals at 115 V_{AC} / 1.5 kW

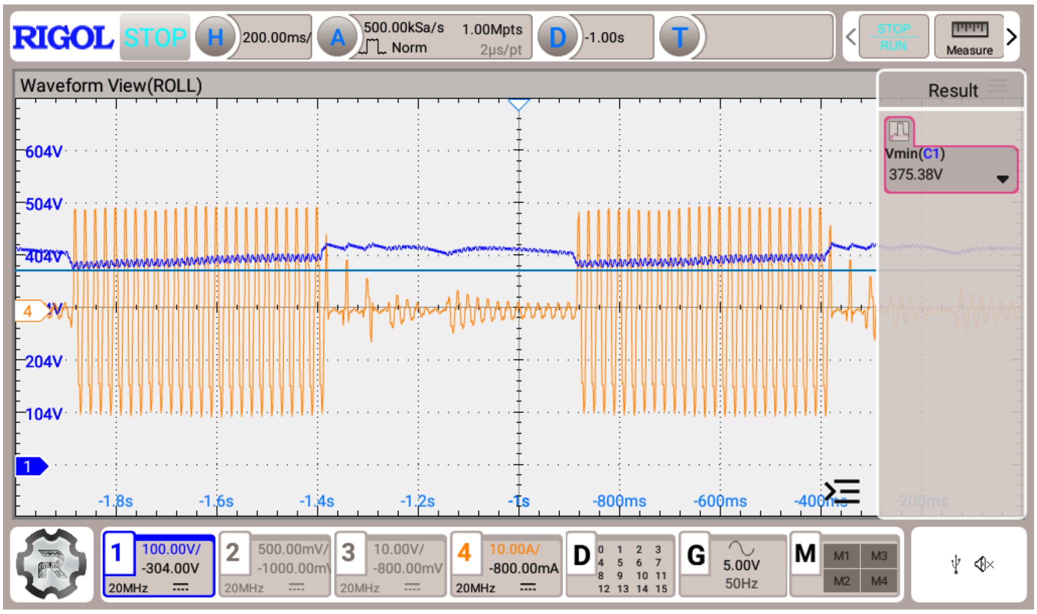


CH 1 – Output voltage (70 V/div) CH 3 – Input current (7.5 A/div) CH 4 – PFC choke current (7.5 A/div)
CH 5 – Low side gate voltage (3 V/div) CH 4 – PFC choke voltage (70 V/div)

Figure 28 – Main signals at 230 V_{AC} / 3 kW

8.4 Dynamic load: step up 10% to 100% and step down 100% to 10%

Transient test continuous at 115 V_{AC}: 500 ms at 0.375 A load current + 500 ms at 3.75 A load current; Slew rate 0.2 A/us



CH 1 – Output voltage (100 V/div) CH 4 – Input current (10 A/div)

Figure 29 – 10% to 100% step load at 115 V_{AC}

Transient test continuous at 230 V_{AC}: 500 ms at 0.75 A load current + 500 ms at 7.5 A load current; Slew rate 0.2 A/us

CH 1 – Output voltage (100 V/div) CH 4 – Input current (10 A/div)

Figure 30 – Dynamic load at 230 V_{AC}

Thermal Results

The HF daughterboard PCB houses two ICeGaN devices, and is equipped with a heatsink mounted on the top side which is cooled by a small 0.9-W fan sitting on the mainboard.

These devices are positioned between the PCB and the heatsink, making it impossible to visually inspect their casing using a thermal camera. However, we utilise the thermal camera to examine the area of the PCB located beneath the devices. This area is coated with copper on the underside, and close to the source of the ICeGaN; this enables to monitor the temperature of the devices. As shown in Figure 9, there are two NTCs near the position of the high–side ICeGaN device to trigger OCP in case the temperature of that area goes beyond 90 ºC

Figure 31 and Figure 32 show the thermal performance of the ICeGaN devices and the PFC inductor at 115 VAC / 1.5 kW conditions after running for 20 minutes. The test was done on the bench at room temperature and temperatures are stable. At 230 VAC / 3 kW the thermal performances is similar.

At 25.1 °C ambient temperature, the backside copper connected to the high–side ICeGaN thermal pad reaches 71.9 °C, which means the temperature increase on the ICeGaN is only 46.8 °C. The PFC choke's magnetic core reaches around 95 °C, so the temperature increase is 68.9 °C.

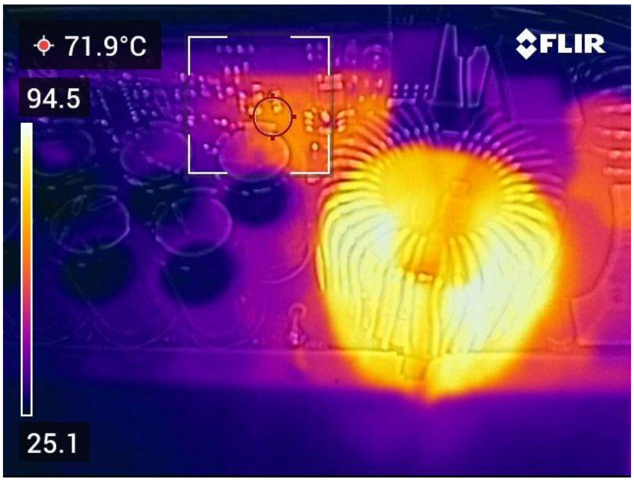


Figure 31 – Fast-leg high-side ICeGaN temperature after 20 min at 115 V_{AC} / 1.5 kW

Figure 32 – PFC inductor temperature after 20 min at 115 VAC / 1.5 kW

.

9 Schematic

9.1 HF daughterboard

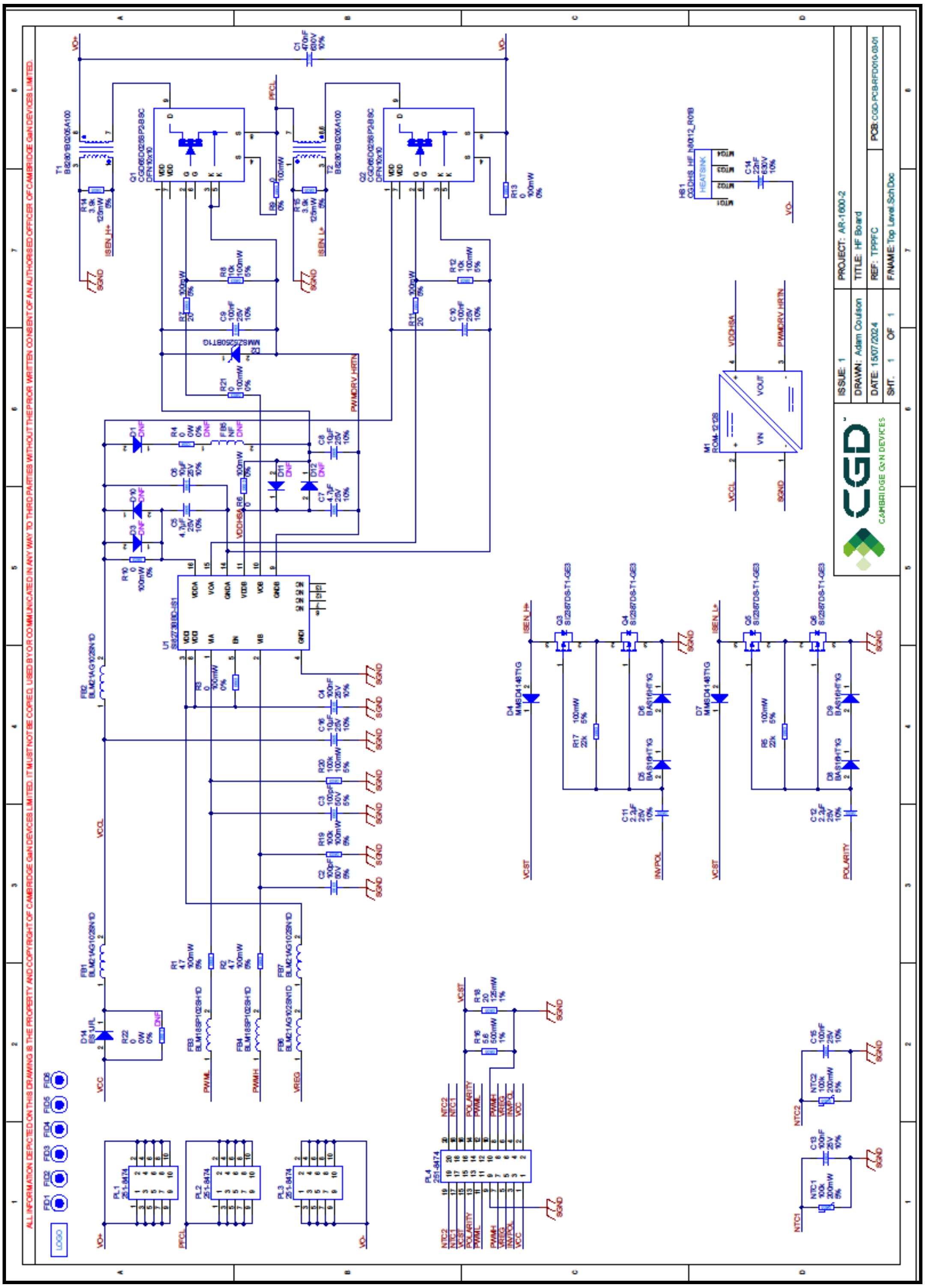


Figure 33 – HF daughterboard schematic

9.2 Control daughterboard

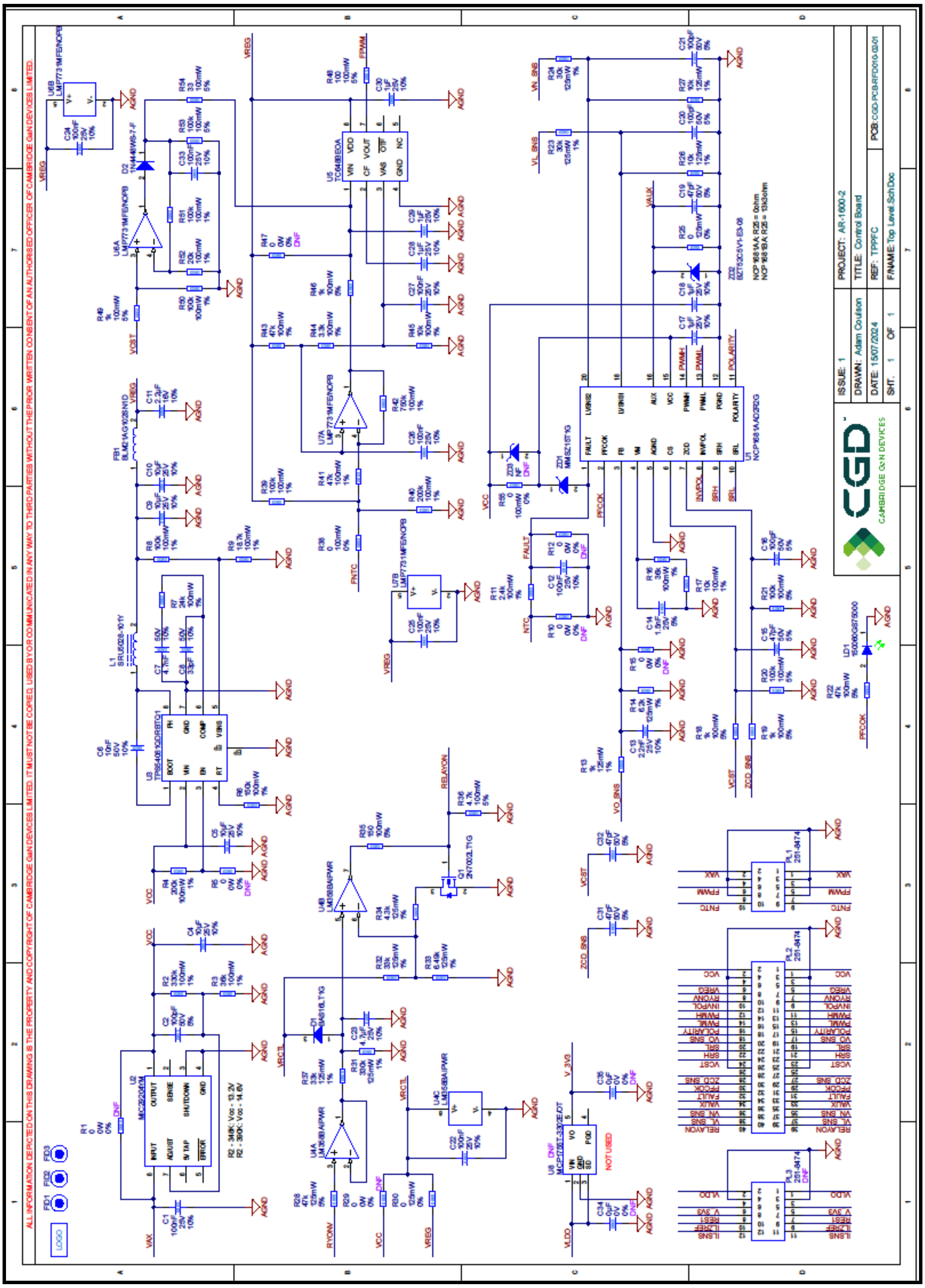


Figure 34 – Control daughterboard schematic

9.3 Auxiliary daughterboard

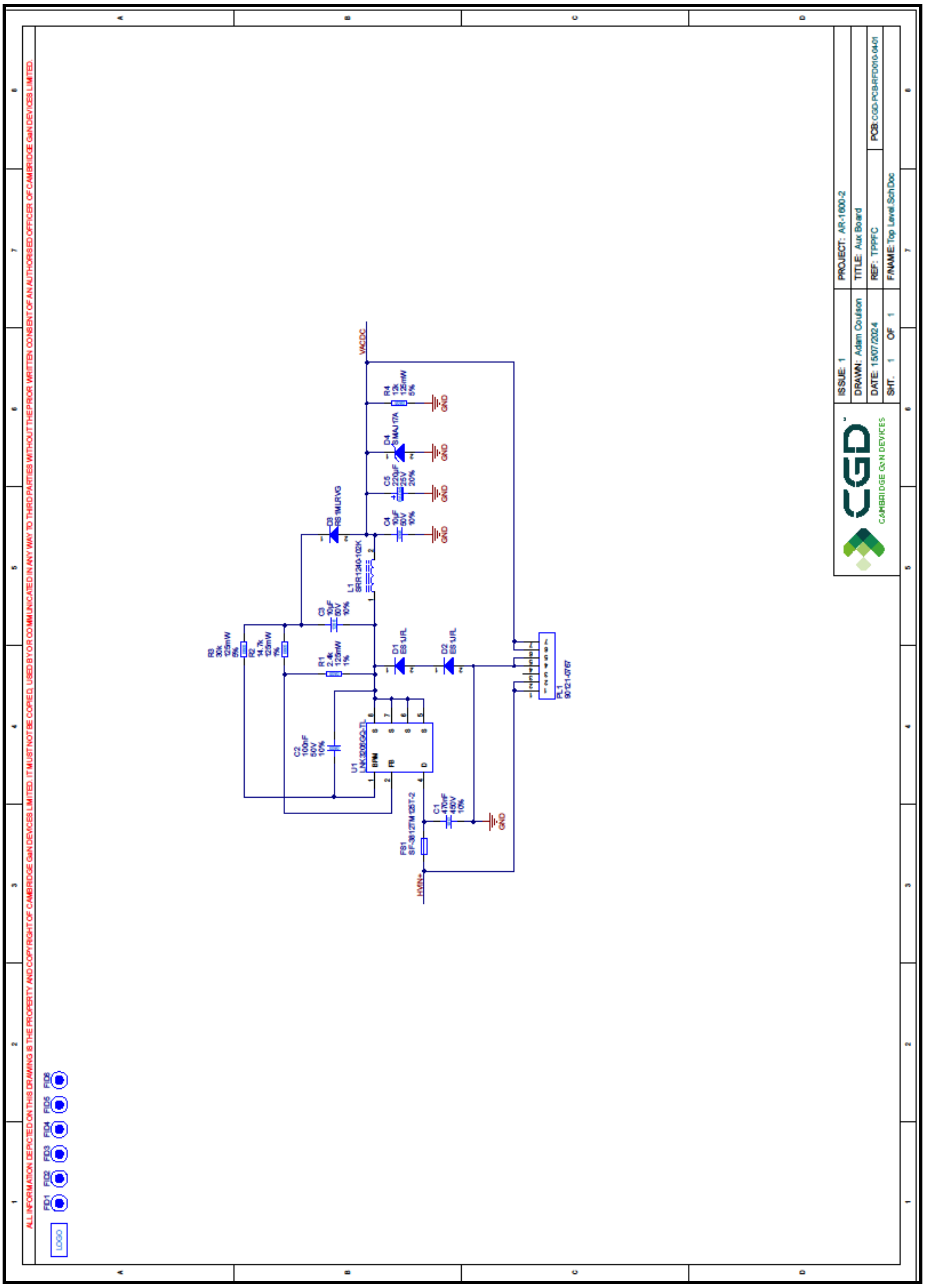


Figure 35 – Auxiliary daughterboard schematic

9.4 Mainboard

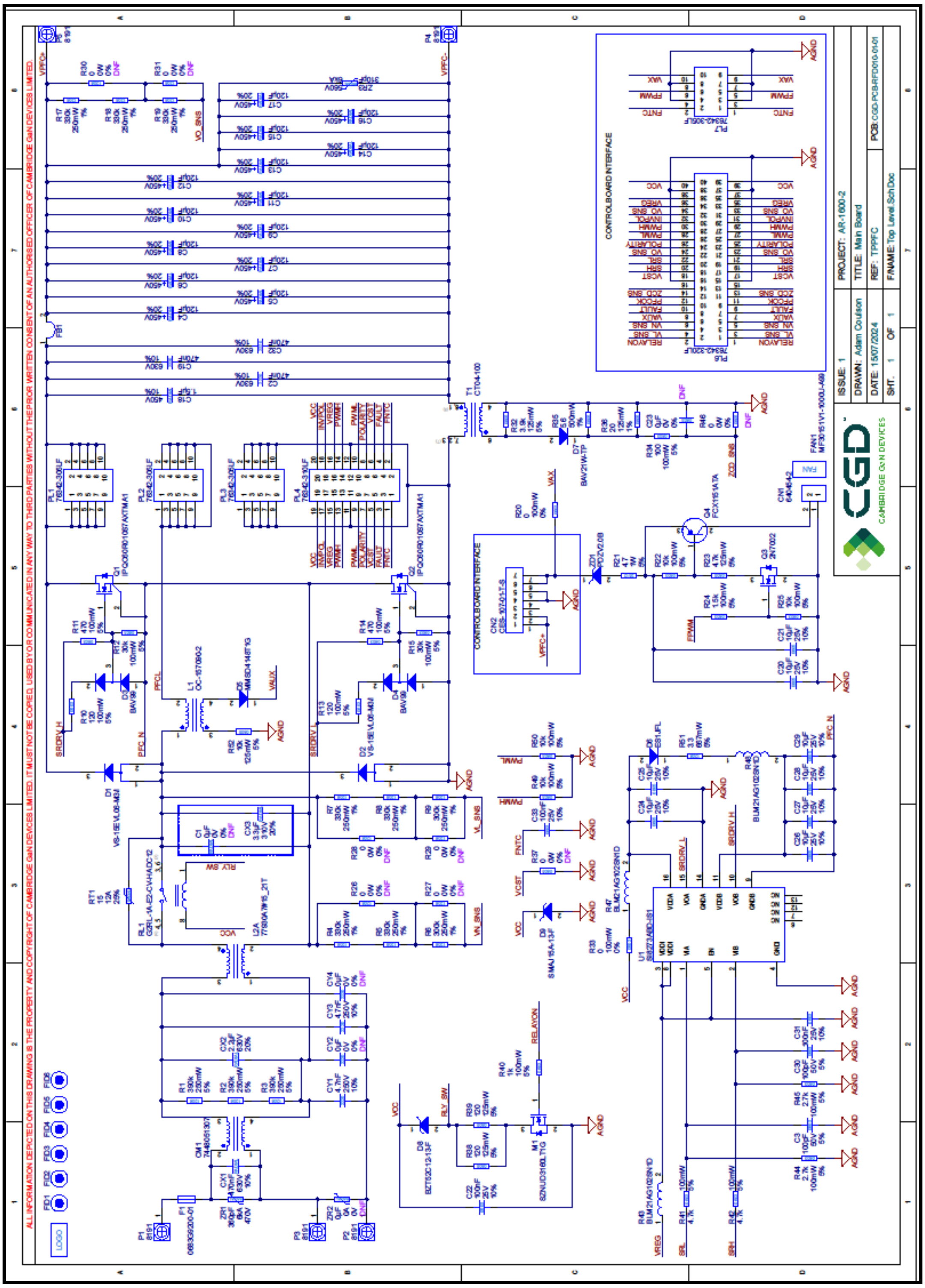


Figure 36 – Mainboard schematic

10 PCB Layout

10.1 HF daughterboard layout

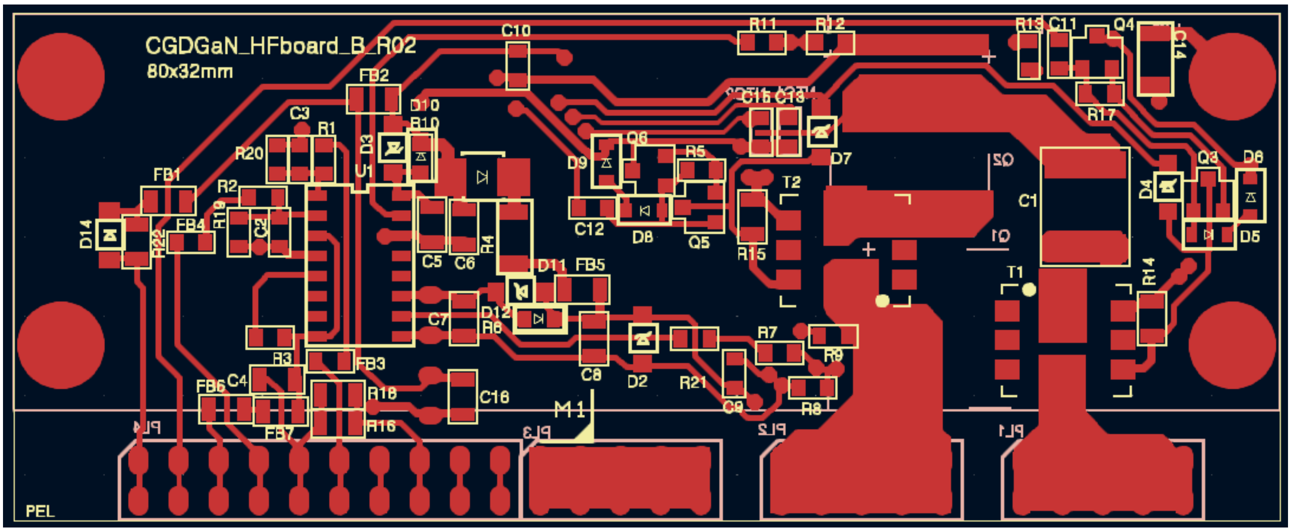


Figure 37 – HF daughterboard layout: top layer

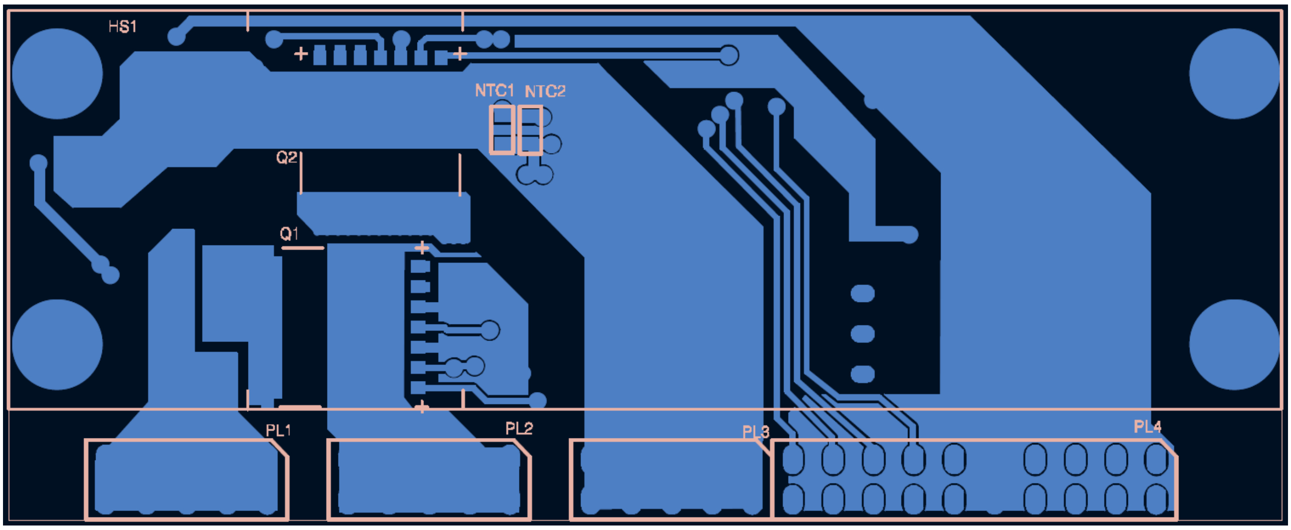


Figure 38 – HF daughterboard layout: bottom layer

10.2 Control daughterboard layout

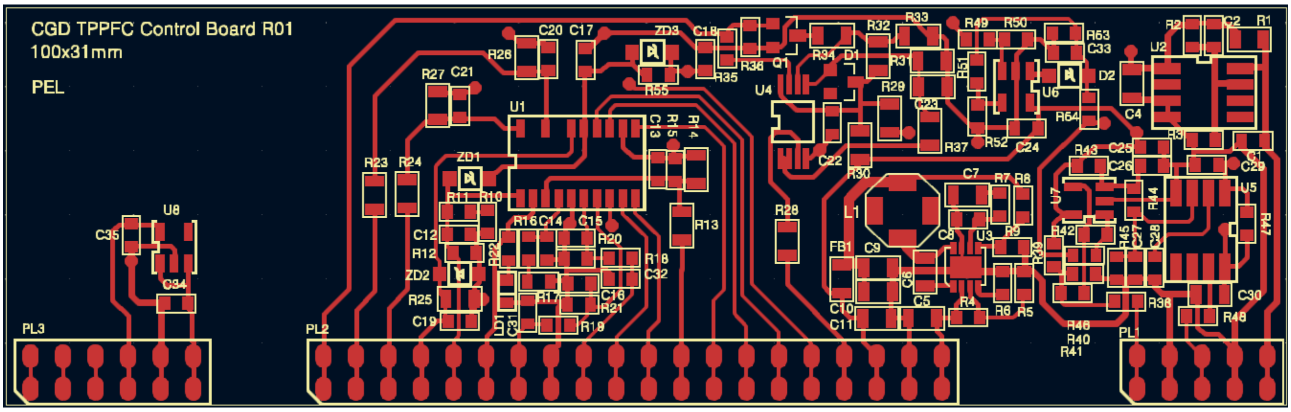


Figure 39 – Control daughterboard layout: top layer

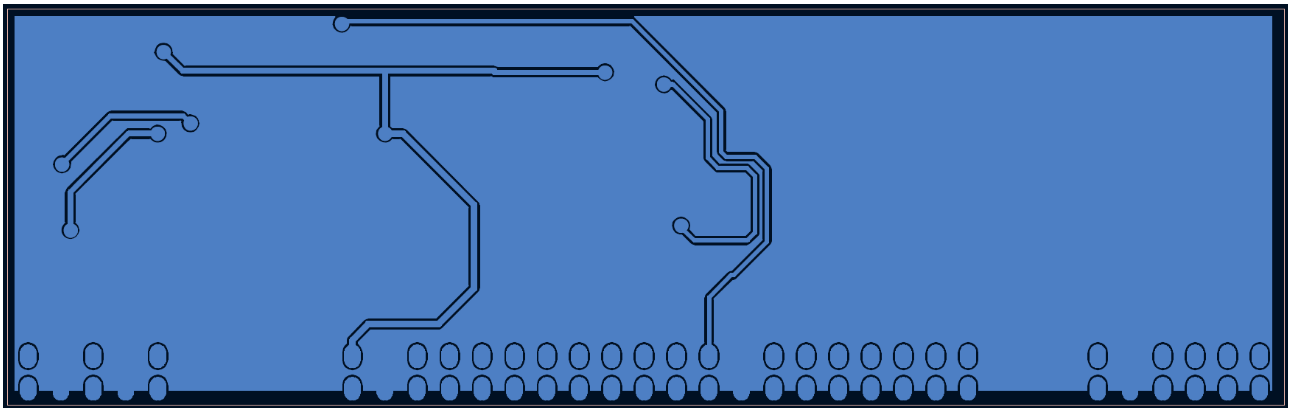


Figure 40 – Control daughterboard layout: bottom layer

10.3 Auxiliary daughterboard layout

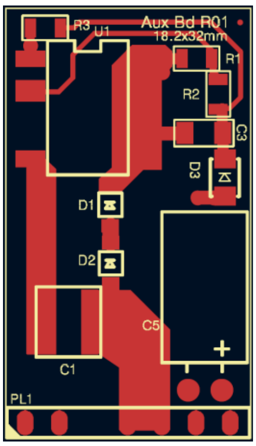


Figure 41 – Auxiliary daughterboard layout: top layer

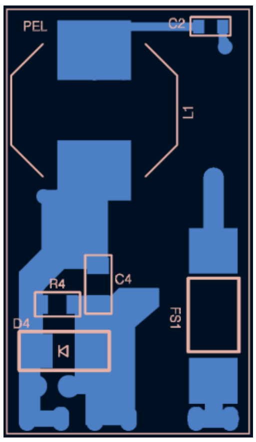


Figure 42 – Auxiliary daughterboard layout: bottom layer

10.4 Mainboard layout

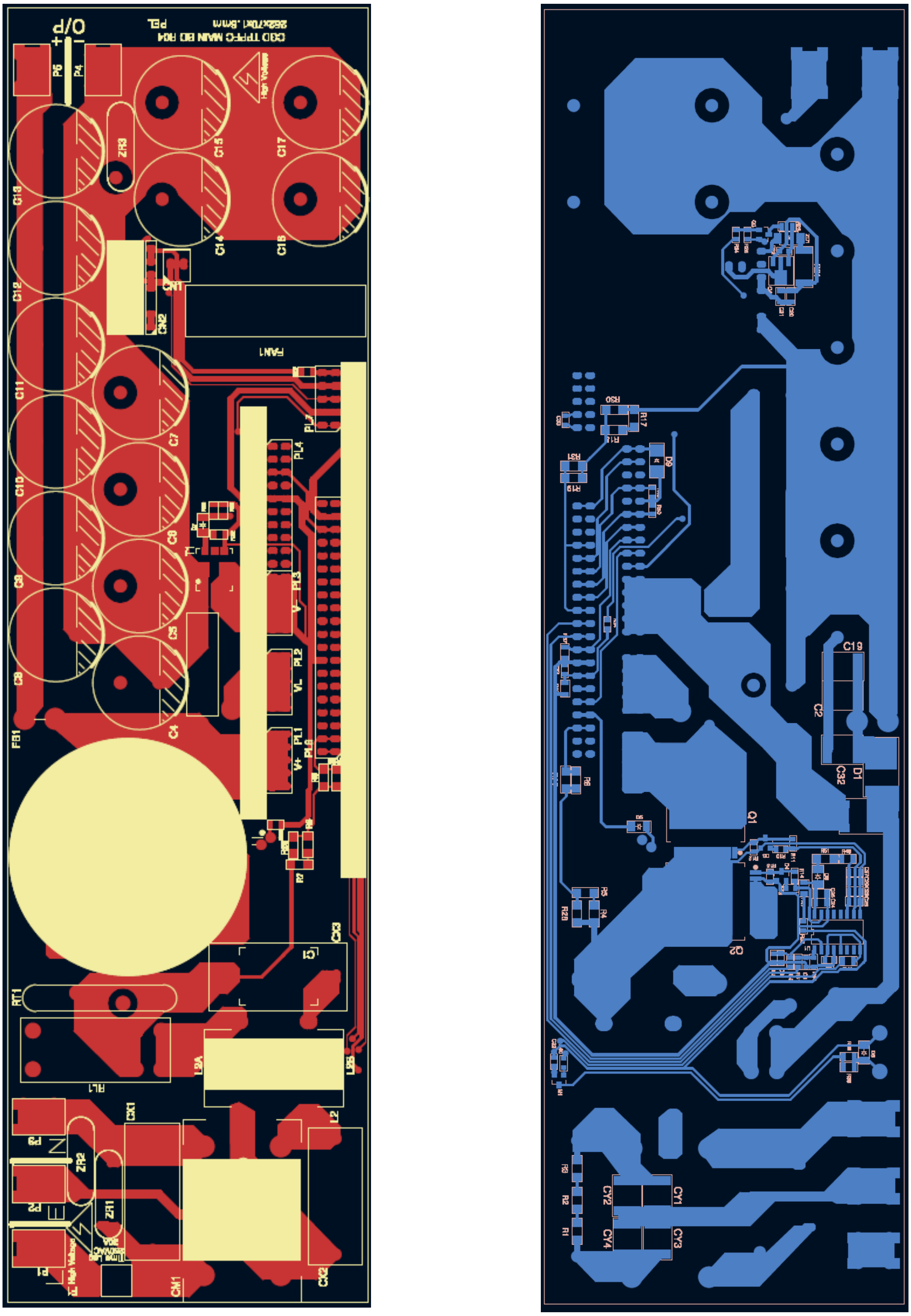


Figure 43 – Mainboard layout. Left: top layer; Right: bottom layer

11 Heatsink Design

Material: Aluminium
t = 1.2 mm
h= 8.0 mm

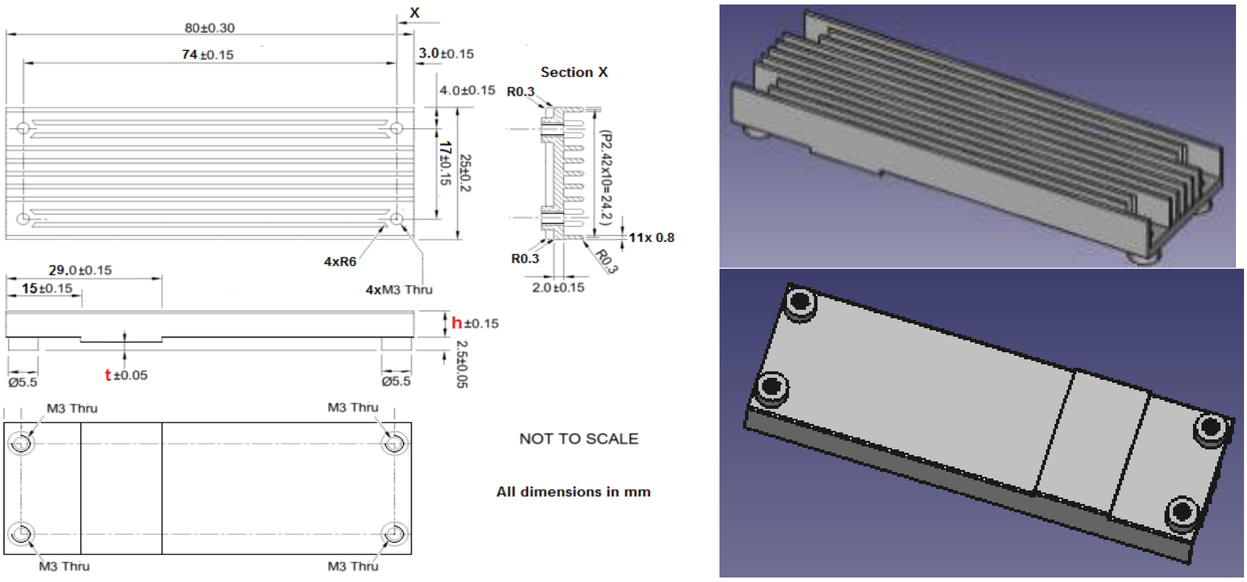


Figure 44 – Heatsinks dimensions and 3D view

12 Bill of Materials (BOM)

Table 8 – CGD 3 kW TPPFC HF daughterboard BOM

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
1	C1	R01	GRM55DR7LV474KW01K	2220	TDK	1	470nF	X7R	630V		Capacitor
2	C2	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
3	C3	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
4	C4	R01	08053C104KAT4A / 885012207072	0805	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
5	C5	R01	08053C475KAT2A	805	AVX	1	4.7uF	X7R	25V		Capacitor
6	C6	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
7	C7	R01	08053C475KAT2A	0805	AVX	1	4.7uF	X7R	25V		Capacitor
8	C8	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
9	C9	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
10	C10	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
11	C11	R01	GRM188Z71E225KE43D	0603	Murata	1	2.2uF	X7R	25V		Capacitor
12	C12	R01	GRM188Z71E225KE43D	0603	Murata	1	2.2uF	X7R	25V		Capacitor
13	C13	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
14	C14	R01	CC1206KKX7RZBB223	1206	Yageo	1	22nF	X7R	630V		Capacitor
15	C15	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
16	C16	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
17	D1	R01	NIL	SMA		0					Diode
18	D2	R01	MMSZ5250B	SOD123	Panjit	1			20V 0.5W		Zener Diode
19	D3	R01	NIL	SOD123		0					Diode
20	D4	R01	MMSD4148T1G	SOD123	Diodes	1			100V 0.2A		Diode
21	D5	R01	BAS16HT1G	SOD323	Onsemi	1			100V 0.2A		Diode
22	D6	R01	BAS16HT1G	SOD323	Onsemi	1			100V 0.2A		Diode
23	D7	R01	MMSD4148T1G	SOD123	Diodes	1			100V 0.2A		Diode
24	D8	R01	BAS16HT1G	SOD323	Onsemi	1			100V 0.2A		Diode
25	D9	R01	BAS16HT1G	SOD323	Onsemi	1			100V 0.2A		Diode
26	D10	R01	NIL	SOD323		0					Diode
27	D11	R01	NIL	SOD123		0					Diode
28	D12	R01	NIL	SOD323		0					Diode
29	D14	R01	ES1JFL	SOD123FL	Onsemi	1					Diode

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
30	FB1	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K bead				Ferrite Bead
31	FB2	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K bead				Ferrite Bead
32	FB3	R01	BLM18SP102SH1D	0603	Murata	1	1K bead				Ferrite Bead
33	FB4	R01	BLM18SP102SH1D	0603	Murata	1	1K bead				Ferrite Bead
34	FB5	R01	NIL	0805	Murata	0	NIL				Ferrite Bead
35	FB6	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K bead				Ferrite Bead
36	FB7	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K bead				Ferrite Bead
37	NTC1	R01	NCP21WF104J03RA	0805	Murata	1	100K	5%			NTC
38	NTC2	R01	NCP21WF104J03RA	0805	Murata	1	100K	5%			NTC
39	PL1	R01	251-8474 (x1/7)		RS	1				Cut to 5pinx2row	Pin header 5pinx2 2.54mm pitch right angle
40	PL2	R01	251-8474 (x1/7)		RS	1				Cut to 5pinx2row	Pin header 5pinx2 2.54mm pitch right angle
41	PL3	R01	251-8474 (x1/7)		RS	1				Cut to 5pinx2row	Pin header 5pinx2 2.54mm pitch right angle
42	PL4	R01	251-8474 (x2/7)		RS	1				Cut to 10pinx2row	Pin header 10pinx2 2.54mm pitch right angle
43	Q1	R01	CGD65D025SH3	T10x10	CGD	1			650V 60A 25mohm	GaN	
44	Q2	R01	CGD65D025SH3	T10x10	CGD	1			650V 60A 25mohm	GaN	
45	Q3	R01	Si2387DS	SOT23	Vishay	1			80V 3A 0.24ohm		MOSFET P-ch
46	Q4	R01	Si2387DS	SOT23	Vishay	1			80V 3A 0.24ohm		MOSFET P-ch
47	Q5	R01	Si2387DS	SOT23	Vishay	1			80V 3A 0.24ohm		MOSFET P-ch
48	Q6	R01	Si2387DS	SOT23	Vishay	1			80V 3A 0.24ohm		MOSFET P-ch
49	R1	R01	RC0603JR-074R7L	0603	Yageo	1	4R7	5%	1/10W		Resistor
50	R2	R01	RC0603JR-074R7L	0603	Yageo	1	4R7	5%	1/10W		Resistor
51	R3	R01	RC0603JR-070RL	0603	Yageo	1	0R	5%	1/10W		Resistor
52	R4	R01	NIL	0603		0	NIL				Resistor
53	R5	R01	RC0603JR-0722KL	0603	Yageo	1	22K	5%	1/10W		Resistor
54	R6	R01	RC0603JR-070RL	0603	Yageo	1	0R	5%	1/10W		Resistor
55	R7	R01	CRCW060320R0JNEA	0603	Vishay	1	20R	5%	1/10W		Resistor
56	R8	R01	RC0603JR-0710KL	0603	Yageo	1	10K	5%	1/10W		Resistor
57	R9	R01	RC0603JR-070RL	0603	Yageo	1	0R	5%	1/10W		Resistor
58	R10	R01	RC0603JR-070RL	0603	Yageo	1	0R	5%	1/10W		Resistor
59	R11	R01	CRCW060320R0JNEA	0603	Vishay	1	20R	5%	1/10W		Resistor
60	R12	R01	RC0603JR-0710KL	0603	Yageo	1	10K	5%	1/10W		Resistor
61	R13	R01	RC0603JR-070RL	0603	Yageo	1	0R	5%	1/10W		Resistor
62	R14	R01	RC0805JR-073K9L	0805	Yageo	1	3K9	5%	1/8W		Resistor
63	R15	R01	RC0805JR-073K9L	0805	Yageo	1	3K9	5%	1/8W		Resistor

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
64	R16	R01	CRCW08055R60FKEAHP	0805	Vishay	1	5R6	1%	1/2W		Resistor
65	R17	R01	RC0603JR-0722KL	0603	Yageo	1	22K	5%	1/10W		Resistor
66	R18	R01	RC0805FR-0720RL	0805	Yageo	1	20R	1%	1/8W		Resistor
67	R19	R01	RC0603JR-07100KL	0603	Yageo	1	100K	5%	1/10W		Resistor
68	R20	R01	RC0603JR-07100KL	0603	Yageo	1	100K	5%	1/10W		Resistor
69	R21	R01	RC0603JR-070RL	0603	Yageo	1	0R	5%	1/10W		Resistor
70	R22	R01	NIL	0603		0	NIL				Resistor
71	T1	R01	B82801B205A100 / 749251100		TDK / Würth Elektronik	1				(**Note**)	Current sense transformer
72	T2	R01	B82801B205A100 / 749251100		TDK / Würth Elektronik	1				(**Note**)	Current sense transformer
73	U1	R01	Si8273BBD-IS1	SOIC16	Skyworks	1			VDDI 2.5-5.5V	H=1.75mm max	IC Gate driver
74	M1	R01	ROM-1212S		Recom	1	12V-12V		1W		DCDC converter isolated
75	PCB	R01	PCB CGD GaN HF Board B R02			1				80x32x1.6mm 2oz (**Note**)	PCB
76	PD1	R01	GP5000S35-0.020-02-0404(x1/15)		Bergquist	1				Cut to (15mm x 25.5 mm)	Gap Pad
77	HS1	R01	HS_HF_h80t12_R01B			1				Ref material: Aluminum 6061	Heatsink
78	S1 - S4	R01	M3x6			4				Flat head	Screw

Note: T1, T2 (TDK P/N B82801B205A100 or WE P/N 749251100) pin1 must be placed at diagonal opposite corner of dot sign of PCB(R02) footprint.

Table 9 – CGD 3 kW TPPFC Control daughterboard BOM

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
1	C1	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
2	C2	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
3	C4	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
4	C5	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
5	C6	R01	C0805Y103K5RACTU / 885012207092	0805	Kemet / Würth Elektronik	1	10nF	X7R	50V		Capacitor
6	C7	R01	08055C472K4T4A / 885012207090	0805	AVX / Würth Elektronik	1	4.7nF	X7R	50V		Capacitor
7	C8	R01	CC0603JRNPO9BN330 / 885012006054	0603	Yageo / Würth Elektronik	1	33pF	C0G	50V		Capacitor
8	C9	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
9	C10	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
10	C11	R01	0805YC225KAT4A / 885012207052	0805	AVX / Würth Elektronik	1	2.2uF	X7R	16V		Capacitor
11	C12	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
12	C13	R01	06033C222KAT4A	0603	AVX	1	2.2nF	X7R	25V		Capacitor

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
13	C14	R01	06033A152JAT2A	0603	AVX	1	1.5nF	C0G	25V		Capacitor
14	C15	R01	CC0603JRNPO9BN470 / 885012006055	0603	Yageo / Würth Elektronik	1	47pF	C0G	50V		Capacitor
15	C16	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
16	C17	R01	06033C105KAT4A / 885012206076	0603	AVX / Würth Elektronik	1	1uF	X7R	25V		Capacitor
17	C18	R01	06033C105KAT4A / 885012206076	0603	AVX / Würth Elektronik	1	1uF	X7R	25V		Capacitor
18	C19	R01	CC0603JRNPO9BN470	0603	Yageo	1	47pF	C0G	50V		Capacitor
19	C20	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
20	C21	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
21	C22	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
22	C23	R01	08053C475KAT2A	0805	AVX	1	4.7uF	X7R	25V		Capacitor
23	C24	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
24	C25	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
25	C26	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
26	C27	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
27	C28	R01	06033C105KAT4A / 885012206076	0603	AVX / Würth Elektronik	1	1uF	X7R	25V		Capacitor
28	C29	R01	06033C105KAT4A / 885012206076	0603	AVX / Würth Elektronik	1	1uF	X7R	25V		Capacitor
29	C30	R01	08053C105KAT2A / 885012207078	0805	AVX / Würth Elektronik	1	1uF	X7R	25V		Capacitor
30	C31	R01	CC0603JRNPO9BN470 / 885012006055	0603	Yageo / Würth Elektronik	1	47pF	C0G	50V		Capacitor
31	C32	R01	CC0603JRNPO9BN470 / 885012006055	0603	Yageo / Würth Elektronik	1	47pF	C0G	50V		Capacitor
32	C33	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
33	C34	R01		0603		0	NIL				Capacitor
34	C35	R01		0603		0	NIL				Capacitor
35	D1	R01	BAS16LT1G	SOT23	Onsemi	1					Diode
36	D2	R01	1N4448WS-7-F	SOD323	Diodes	1					Diode
37	FB1	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K bead				Ferrite Bead
38	L1	R01	SRU5028-101Y		Bourns	1	100uH	30%			Inductor
39	LD1	R01	150060GS75000	0603	Wurth Elektronik	1	Green				LED
40	PL1	R01	251-8474 (x1/7)		RS	1				Cut to 5pinx2row	Pin header 5pinx2 2.54mm pitch right angle

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
41	PL2	R01	251-8474 (x4/7)		RS	1				Cut to 20pinx2row	Pin header 20pinx2 2.54mm pitch right angle
42	PL3	R01				0	NIL				Pin header
43	Q1	R01	2N7002LT1G	SOT23	Onsemi	1					MOSFET N-ch
44	R1	R01		0805		0	NIL				Resistor
45	R2	R01	RC0603FR-07330KL	0603	Yageo	1	330K	0.01	1/10W		Resistor
46	R3	R01	RC0603FR-0736KL	0603	Yageo	1	36K	0.01	1/10W		Resistor
47	R4	R01	RC0603FR-07200KL	0603	Yageo	1	200K	0.01	1/10W		Resistor
48	R5	R01		0603		0	NIL		1/10W		Resistor
49	R6	R01	RC0603FR-07150KL	0603	Yageo	1	150K	1%	1/10W		Resistor
50	R7	R01	RC0603FR-0724KL	0603	Yageo	1	24K	1%	1/10W		Resistor
51	R8	R01	RC0603FR-07100KL	0603	Yageo	1	100K	1%	1/10W		Resistor
52	R9	R01	RC0603FR-0718K7L	0603	Yageo	1	18K7	0.01	1/10W		Resistor
53	R10	R01		0603		0	NIL				Resistor
54	R11	R01	RC0603FR-072K4L	0603	Yageo	1	2K4	1%	1/10W		Resistor
55	R12	R01		0603		0	NIL				Resistor
56	R13	R01	RC0805FR-071KL	0805	Yageo	1	1K	1%	1/8W		Resistor
57	R14	R01	RC0805FR-076K2L	0805	Yageo	1	6K2	1%	1/8W		Resistor
58	R15	R01		0603		0	NIL				Resistor
59	R16	R01	RC0603FR-0736KL	0603	Yageo	1	36K	1%	1/10W		Resistor
60	R17	R01	RC0603FR-0710KL	0603	Yageo	1	10K	1%	1/10W		Resistor
61	R18	R01	RC0603JR-071KL	0603	Yageo	1	1K	5%	1/10W		Resistor
62	R19	R01	RC0603JR-071KL	0603	Yageo	1	1K	5%	1/10W		Resistor
63	R20	R01	RC0603JR-07100KL	0603	Yageo	1	100K	5%	1/10W		Resistor
64	R21	R01	RC0603JR-07100KL	0603	Yageo	1	100K	5%	1/10W		Resistor
65	R22	R01	RC0603JR-0747KL	0603	Yageo	1	47K	5%	1/10W		Resistor
66	R23	R01	RC0805FR-0730KL	0805	Yageo	1	30K	1%	1/8W		Resistor
67	R24	R01	RC0805FR-0730KL	0805	Yageo	1	30K	1%	1/8W		Resistor
68	R25	R01	RC0805JR-070RL	0805	Yageo	1	0R	5%	1/8W		Resistor
69	R26	R01	RC0805FR-0710KL	0805	Yageo	1	10K	1%	1/8W		Resistor
70	R27	R01	RC0805FR-0710KL	0805	Yageo	1	10K	0.01	1/8W		Resistor
71	R28	R01	RC0805JR-0747KL	0805	Yageo	1	47K	0.05	1/8W		Resistor
72	R29	R01		0805		0	NIL				Resistor
73	R30	R01	RC0805JR-070RL	0805	Yageo	1	0R	0.05	1/8W		Resistor
74	R31	R01	RC0805FR-07330KL	0805	Yageo	1	330K	0.01	1/8W		Resistor
75	R32	R01	RC0805FR-0733KL	0805	Yageo	1	33K	0.01	1/8W		Resistor
76	R33	R01	RC0805FR-076K49L	0805	Yageo	1	6K49	0.01	1/8W		Resistor
77	R34	R01	RC0805FR-074K3L	0805	Yageo	1	4K3	0.01	1/8W		Resistor
78	R35	R01	RC0603JR-07150RL	0603	Yageo	1	150R	0.05	1/10W		Resistor
79	R36	R01	RC0603JR-074K7L	0603	Yageo	1	4K7	0.05	1/10W		Resistor
80	R37	R01	RC0805FR-0733KL	0805	Yageo	1	33K	0.01	1/8W		Resistor
81	R38	R01	RC0603JR-070RL	0603	Yageo	1	0R	0.05	1/10W		Resistor
82	R39	R01	RC0603FR-07100KL	0603	Yageo	1	100K	0.01	1/10W		Resistor
83	R40	R01	RC0603FR-07200KL	0603	Yageo	1	200K	0.01	1/10W		Resistor
84	R41	R01	RC0603FR-0747KL	0603	Yageo	1	47K	0.01	1/10W		Resistor
85	R42	R01	RC0603FR-07750KL	0603	Yageo	1	750K	0.01	1/10W		Resistor
86	R43	R01	RC0603FR-0747KL	0603	Yageo	1	47K	0.01	1/10W		Resistor
87	R44	R01	RC0603FR-073K3L	0603	Yageo	1	3K3	0.01	1/10W		Resistor
88	R45	R01	RC0603FR-0710KL	0603	Yageo	1	10K	0.01	1/10W		Resistor
89	R46	R01	RC0603JR-071KL	0603	Yageo	1	1K	0.05	1/10W		Resistor
90	R47	R01		0603		0	NIL				Resistor
91	R48	R01	RC0603JR-07100RL	0603	Yageo	1	100R	0.05	1/10W		Resistor
92	R49	R01	RC0603JR-071KL	0603	Yageo	1	1K	0.05	1/10W		Resistor
93	R50	R01	RC0603FR-07100KL	0603	Yageo	1	100K	0.01	1/10W		Resistor
94	R51	R01	RC0603FR-07100KL	0603	Yageo	1	100K	0.01	1/10W		Resistor
95	R52	R01	RC0603FR-0720KL	0603	Yageo	1	20K	0.01	1/10W		Resistor
96	R53	R01	RC0603JR-07100KL	0603	Yageo	1	100K	0.05	1/10W		Resistor
97	R54	R01	RC0603JR-0733RL	0603	Yageo	1	33R	0.05	1/10W		Resistor
98	R55	R01	RC0603JR-070RL	0603	Yageo	1	0R	0.05	1/10W		Resistor
99	U1	R01	NCP1681AAD2R2G	SOIC20NB	Onsemi	1					IC Totem pole PFC controller

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
100	U2	R01	MIC29204YM	SOIC8	Microchip	1					IC LDO
101	U3	R01	TPS54061QDRBTQ1	VSON8	TI	1					IC Buck Regulator
102	U4	R01	LM358BAIPWR	TSSOP8	TI	1					IC Opamp
103	U5	R01	TC648BEOA	SOIC8	Microchip	1					IC Fan controller
104	U6	R01	LMP7731MFE/NOPB	SOT23-5	TI	1					IC Opamp
105	U7	R01	LMP7731MFE/NOPB	SOT23-5	TI	1					IC Opamp
106	U8	R01	NIL	SOT23-5		0	NIL				
107	ZD1	R01	MMSZ15T1G	SOD123	Onsemi	1					Zener Diode
108	ZD2	R01	BZT52C5V1-E3-08	SOD123	Vishay	1					Zener Diode
109	ZD3	R01	NIL	SOD123		0	NIL				Zener Diode
110	PCB	R01	PCB CGD TPPFC Control Board R01			1				100x31x1.2mm 1oz	PCB

Table 10 – CGD 3 kW TPPFC Auxiliary daughterboard BOM

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
1	C1	R01	C4532X7T2W474K230KA	1812	TDK	1	470nF	450V	X7T		Capacitor
2	C2	R01	CC0603KRX7R9BB104 / 885012206095	0603	Yageo / Würth Elektronik	1	100nF	50V	X7R		Capacitor
3	C3	R01	CL31B106KBHNNNE	1206	Samsung	1	10uF	50V	X7R		Capacitor
4	C4	R01	CL31B106KBHNNNE	1206	Samsung	1	10uF	50V	X7R		Capacitor
5	C5	R01	25YXJ220M6.3X11	D6.3X11	Rubycon	1	220uF	25V			Capacitor, Electrolytic
6	D1	R01	ES1JFL	SOD123FL	Onsemi	1					Diode
7	D2	R01	ES1JFL	SOD123FL	Onsemi	1					Diode
8	D3	R01	RS1MLRVG	SubSMA	Taiwan semiconductor	1			1kV 0.8A		Diode
9	D4	R01	SMAJ17A	SMA	LittelFuse	1					Diode
10	FS1	R01	SF-3812TM125T-2		Bourns	1	1.25A		600Vac		Fuse
11	L1	R01	SRR1240-102K		Bourns	1	1mH				Inductor
12	PL1	R01	90121-0927		MOLEX	1				Remove pin3	Pin header 7pin 2.54mm right angle
13	R1	R01	RC0805FR-072K4L	0805	Yageo	1	2K4	0.01	1/8W		Resistor
14	R2	R01	RC0805FR-0714K7L	0805	Yageo	1	14K7	0.01	1/8W		Resistor
15	R3	R01	RC0805JR-0730KL	0805	Yageo	1	30K	0.05	1/8W		Resistor
16	R4	R01	RC0805JR-0712KL	0805	Yageo	1	12K	0.05	1/8W		Resistor
17	U1	R01	LNK3206GQ	SMD-8C	PI	1					IC, switcher
18	PCB	R01	PCB TPPFC Aux Board R01			1				18.2x32x1.2mm 2oz	PCB

Table 11 – CGD 3 kW TPPFC Mainboard BOM

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
1	C1	R01				0	NIL				Capacitor, MPP
2	C2	R01	GRM55DR7LV474KW01K	2220	Murata	1	470nF	X7R	630V		Capacitor

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
3	C3	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
4	C4	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
5	C5	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
6	C6	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
7	C7	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
8	C8	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
9	C9	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
10	C10	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
11	C11	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
12	C12	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
13	C13	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
14	C14	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
15	C15	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
16	C16	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
17	C17	R01	450LXW120MEFR18X30	18x30	Rubycon	1	120uF	0.2	450V		Capacitor, Electrolytic
18	C18	R01	ECQ-E2W155KH		Panasonic	1	1.5uF	0.1	450V		Capacitor, MPP
19	C19	R01	GRM55DR7LV474KW01K	2220	Murata	1	470nF	X7R	630V		Capacitor
20	C20	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
21	C21	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
22	C22	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
23	C23	R01		0603		0	NIL				Capacitor
24	C24	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
25	C25	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
26	C26	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
27	C27	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
28	C28	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
29	C29	R01	CL21B106KAYQNNE	0805	Samsung	1	10uF	X7R	25V		Capacitor
30	C30	R01	CC0603JRNPO9BN101 / 885012006057	0603	Yageo / Würth Elektronik	1	100pF	C0G	50V		Capacitor
31	C31	R01	06033C104KAT2A / 885012206071	0603	AVX / Würth Elektronik	1	100nF	X7R	25V		Capacitor
32	C32	R01	GRM55DR7LV474KW01K	2220	Murata	1	470nF	X7R	630V		Capacitor
33	C33	R01	06033C104KAT2A	0603	AVX	1	100nF	X7R	25V		Capacitor
34	CM1	R01	7448051307		Würth Elektronik	1	7mH 13A				Common mode choke
35	CN1	R01	640454-2	P=2.54mm, 2P	TE connectivity	1					Header, 2pin
36	CN2	R01	CES-107-01-T-S	P=2.54mm, 6P	Samtec	1					Header, 6pin
37	CX1	R01	F862DO474K310ZLH0J	26x10x18.5 mmH	Kemet	1	0.47uF	10%	310Vac		Capacitor, Safety, X2
38	CX2	R01	F861DU225M310Z		Kemet	1	2.2uF	20%	310Vac		Capacitor, Safety, X2
39	CX3	R01	F861DY335M310ZLH0J		Kemet	1	3.3uF	0.2	310Vac		Capacitor, Safety, X2

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
40	CY1	R01	GA355DR7GF472KW01L		Murata	1	4.7nF	X7R	250Vac		Capacitor, Safety, Y2
41	CY2	R01				0	NIL				Capacitor, Safety, Y2
42	CY3	R01	GA355DR7GF472KW01L		Murata	1	4.7nF	X7R	250Vac		Capacitor, Safety, Y2
43	CY4	R01				0	NIL				Capacitor, Safety, Y2
44	D1	R01	VS-15EVL06-M3	SlimDPAK	Vishay	1					Diode, Rectifier, Fast Recovery
45	D2	R01	VS-15EVL06-M3	SlimDPAK	Vishay	1					Diode, Rectifier, Fast Recovery
46	D3	R01	BAV99	SOT23	Onsemi	1					Diode
47	D4	R01	BAV99	SOT23	Onsemi	1			70 V, 200 mA		Diode
48	D5	R01	MMSD4148T1G	SOD123	Diodes	1					Diode
49	D6	R01	ES1JFL	SOD123FL	Onsemi	1					Diode
50	D7	R01	BAV21W	SOD123	Diodes	1			250V		Diode
51	D8	R01	BZT52C12-13-F	SOD123	Diodes	1			12V 500mW		Zener diode
52	D9	R01	SMAJ15A-13-F	SMA	Diodes	1					Diode
53	F1	R01	0683G9200-01		Bel	1	20A Time Lag		300Vac		Fuse
54	FAN1	R01	MF30151V1-1000U-A99		Sunon	1				With 2pin connector 2.54mm	Fan
55	FB1	R01	Jumper wire dia1.2mm Pitch=6mm	P=6mm		1					Jumper wire, coated
56	L1	R01	OC-157090-2 x2 39T AWG#15			1	368uH				PFC choke
57	L2A	R01	77930A7#15_21T (L2A)			1	69uH				Differential choke
58	L2B	R01	Jumper wire dia1.2mm Pitch=18mm	P=18mm		1					Jumper wire, coated
59	M1	R01	SZNUD3160LT1G	SOT23	Onsemi	1			60V		Inductive Load driver
60	P1	R01	8191		Keystone	1					Screw Terminal
61	P2	R01	8191		Keystone	1					Screw Terminal
62	P3	R01	8191		Keystone	1					Screw Terminal
63	P4	R01	8191		Keystone	1					Screw Terminal
64	P5	R01	8191		Keystone	1					Screw Terminal
65	PL1	R01	76342-305LF	P=2.54mm, 5Px2	FCI	1					Header 5pinx2
66	PL2	R01	76342-305LF	P=2.54mm, 5Px2	FCI	1					Header 5pinx2
67	PL3	R01	76342-305LF	P=2.54mm, 5Px2	FCI	1					Header 5pinx2
68	PL4	R01	76342-310LF	P=2.54mm, 10Px2	FCI	1					Header 10pinx2
69	PL6	R01	76342-320LF	P=2.54mm, 20Px2	FCI	1					Header 20pinx2
70	PL7	R01	76342-305LF	P=2.54mm, 5Px2	FCI	1					Header 5pinx2
71	Q1	R01	IPQC60R010S7A	PG-HDSOP-22	Infineon	1	10mo hm		650V, 50A		MOSFET N-ch power
72	Q2	R01	IPQC60R010S7A	PG-HDSOP-22	Infineon	1	10mo hm		650V, 50A		MOSFET N-ch power
73	Q3	R01	2N7002	SOT23	Onsemi	1					MOSFET N-ch
74	Q4	R01	FCX1151ATA	SOT89	Diodes	1					Transistor PNP
75	R1	R01	RC1206JR-7W390KL	1206	Yageo	1	390K	0.05	1/4W		Resistor

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
76	R2	R01	RC1206JR-7W390KL	1206	Yageo	1	390K	0.05	1/4W		Resistor
77	R3	R01	RC1206JR-7W390KL	1206	Yageo	1	390K	0.05	1/4W		Resistor
78	R4	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
79	R5	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
80	R6	R01	KTR18EZPF3003	1206	Rohm	1	300K	0.01	1/4W		Resistor
81	R7	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
82	R8	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
83	R9	R01	KTR18EZPF3003	1206	Rohm	1	300K	0.01	1/4W		Resistor
84	R10	R01	RC0603JR-07120RL	0603	Yageo	1	120R	0.05	1/10W		Resistor
85	R11	R01	RC0603JR-07470RL	0603	Yageo	1	470R	0.05	1/10W		Resistor
86	R12	R01	RC0603JR-0730KL	0603	Yageo	1	30K	0.05	1/10W		Resistor
87	R13	R01	RC0603JR-07120RL	0603	Yageo	1	120R	0.05	1/10W		Resistor
88	R14	R01	RC0603JR-07470RL	0603	Yageo	1	470R	0.05	1/10W		Resistor
89	R15	R01	RC0603JR-0730KL	0603	Yageo	1	30K	0.05	1/10W		Resistor
90	R17	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
91	R18	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
92	R19	R01	KTR18EZPF3303	1206	Rohm	1	330K	0.01	1/4W		Resistor
93	R20	R01	RC0603JR-070RL	0805	Yageo	1	0R	0.05	1/8W		Resistor
94	R21	R01	ERJ-1TYJ4R7U	2512	Panasonic	1	4.7R	0.05	1W		Resistor
95	R22	R01	RC0603JR-0710KL	603	Yageo	1	10K	0.05	1/10W		Resistor
96	R23	R01	RC0805JR-074K7L	805	Yageo	1	4K7	0.05	1/8W		Resistor
97	R24	R01	RC0603JR-071K5L	0603	Yageo	1	1k5	0.05	1/10W		Resistor
98	R25	R01	RC0603JR-0710KL	0603	Yageo	1	10K	0.05	1/10W		Resistor
99	R26	R01		1206		0	NIL				Resistor
100	R27	R01		1206		0	NIL				Resistor
101	R28	R01		1206		0	NIL				Resistor
102	R29	R01		1206		0	NIL				Resistor
103	R30	R01		1206		0	NIL				Resistor
104	R31	R01		1206		0	NIL				Resistor
105	R32	R01	RC0805JR-073K9RL	0805	Yageo	1	3K9	0.05	1/8W		Resistor
106	R33	R01	RC0603JR-070RL	0603	Yageo	1	0R	0.05	1/10W		Resistor
107	R34	R01	RC0603JR-07100RL	0603	Yageo	1	100R	0.05	1/10W		Resistor
108	R35	R01	CRCW08055R60FKEAHP	0805	Vishay	1	5R6	0.01	1/2W		Resistor
109	R36	R01	RC0805FR-0720RL	0805	Yageo	1	20R	0.01	1/8W		Resistor
110	R37	R01		0805		0	NIL				Resistor
111	R38	R01	RC0805JR-07120RL	0805	Yageo	1	120R	0.05	1/8W		Resistor
112	R39	R01	RC0805JR-07120RL	0805	Yageo	1	120R	0.05	1/8W		Resistor
113	R40	R01	RC0603JR-071KL	0603	Yageo	1	1K	0.05	1/10W		Resistor
114	R41	R01	RC0603JR-074K7L	0603	Yageo	1	4K7	0.05	1/10W		Resistor
115	R42	R01	RC0603JR-074K7L	0603	Yageo	1	4K7	0.05	1/10W		Resistor
116	R43	R01	BLM21AG102SN1	0805	Murata	1	1K Bead				Ferrite Bead
117	R44	R01	RC0603JR-072K7L	0603	Yageo	1	2K7	0.05	1/10W		Resistor
118	R45	R01	RC0603JR-072K7L	0603	Yageo	1	2K7	0.05	1/10W		Resistor
119	R46	R01		0805		0	NIL				Resistor
120	R47	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K Bead				Ferrite Bead
121	R48	R01	BLM21AG102SN1 / 742792096	0805	Murata / Würth Elektronik	1	1K Bead				Ferrite Bead
122	R49	R01	RC0603JR-0710KL	0603	Yageo	1	10K	0.05	1/10W		Resistor
123	R50	R01	RC0603JR-0710KL	0603	Panasonic	1	10K	0.05	1/10W		Resistor
124	R51	R01	ERJ-P08J3R3V	1206	Yageo	1	3R3	0.05	2/3W	Anti-surge	Resistor
125	R52	R01	RC0805JR-0710KL	0805	Yageo	1	10K	0.05	1/8W		Resistor
126	RL1	R01	G2RL-1A-E2-CV-HA DC12		OMRON	1			250V 23A, 12Vdc		Relay
127	RT1	R01	MS32 15012	D31XT6	Ametherm	1	15ohm				Thermistor
128	T1	R01	CT04-100		ICE	1					Current sense transformer
129	U1	R01	Si8273ABD-IS1	SOIC16	Silicon Lab	1					IC Gate driver
130	ZD1	R01	PDZV2.0B	SOD128	Rohm	1			2V, 1W		Zener diode

No	Designator	Updated in BOM Revision	Part No.	Package	Manufacturer	Qty	Value	Tolerance	Voltage, Current, Power	Remark	Description
131	ZR1	R01	ERZ-E11A471		Panasonic	1					Varistor
132	ZR2	R01	NIL			0					Varistor
133	ZR3	R01	ERZ-E11A561		Panasonic	1					Varistor
134	Spacer	R01	785-0805 (x1/24)		RS Pro	1				Cut to 48x46mm, L1 insulation spacer	Polypropylene Plastic Film
135	PCB	R01	PCB TPPFC Main Board R04			1				252x70x1.6mm 2oz	PCB
136	Stand	R01	M3 Hex stand nylon 8mm			5				Option	Stand Nylon
137	Screw	R01	M3x6 nylon			5				Option	Screw Nylon
138	FanS	R01	Spacer block, Acrylic, 30x15x5mm			1				Option	Fan spacer
139	CTie1	R01	664-2887		RS	2				between fan and PCB	Cable tie
140	CTie2	R01				2				between L1 and PCB	Cable tie

13 References

[1] ICeGaN™ DHDFN package [CGD – AN2401]

14 List of Figures

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