TP44400SG-QRF45-EVB

45W QRF USB PD Charger Evaluation Board

using

Tagore Technology's Superior GaN FET (TP44400SG)

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About this document

Objective and Purpose

This application note describes Tagore Technology's 45W QRF based USB PD charger Evaluation Board (EVB, TP44400SG-QRF45-EVB) using its 360 mΩ superior GaN FET (TP44400SG). The user will be able to perform complete evaluation of the EVB by following the procedures outlined in this document and all the necessary supporting information (circuit schematics, BOM, layout, key operating waveforms, etc.) are provided to facilitate a quick adaption to a production design.

Intended audience

This application note is intended for Tagore Technology's customers and partners using its 360 mΩ superior GaN FET (TP44400SG).

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1 INTRODUCTION

This document presents a technical report describing a 45W Quasi Resonant Flyback (QRF) converter-based USB PD charger Evaluation Board (EVB) TP44400SG-QRF45-EVB with 5V/3A, 9V/3A, 15V/3A, 20V/2.25A programmable outputs. It uses Tagore Technology's 360 mΩ superior GaN FET IC TP44400SG, and On Semiconductor's Quasi Resonant Flyback (QRF) controller NCP1342 to achieve high power density and efficiency. The flyback converter works in the principle of DCM QR valley switching. It helps reduce the turn on switching losses due to PCB parasitic capacitances. The EVB works with universal AC input voltage and frequency ranges (90 – 265 Vrms, and 50-60 Hz), while delivering a peak output power of 45W at 20V DC output. This design report presents the power supply specifications, circuit schematics, PCB layouts, bill of materials, and measured performance data.

Figure 1 shows different views of the EVB. The AC input power connectors are placed at one end of the power board. The output USB C connector is located on the main daughter card. There is another small daughter card, where two input diode bridges (connected in parallel) are placed. A PI filter is used in the HV DC bus to improve the EMI performance. It is formed using two electrolytic capacitors (68 µF, 400V and 22 µF, 400V), and a 100 µH Differential Mode (DM) filter choke.

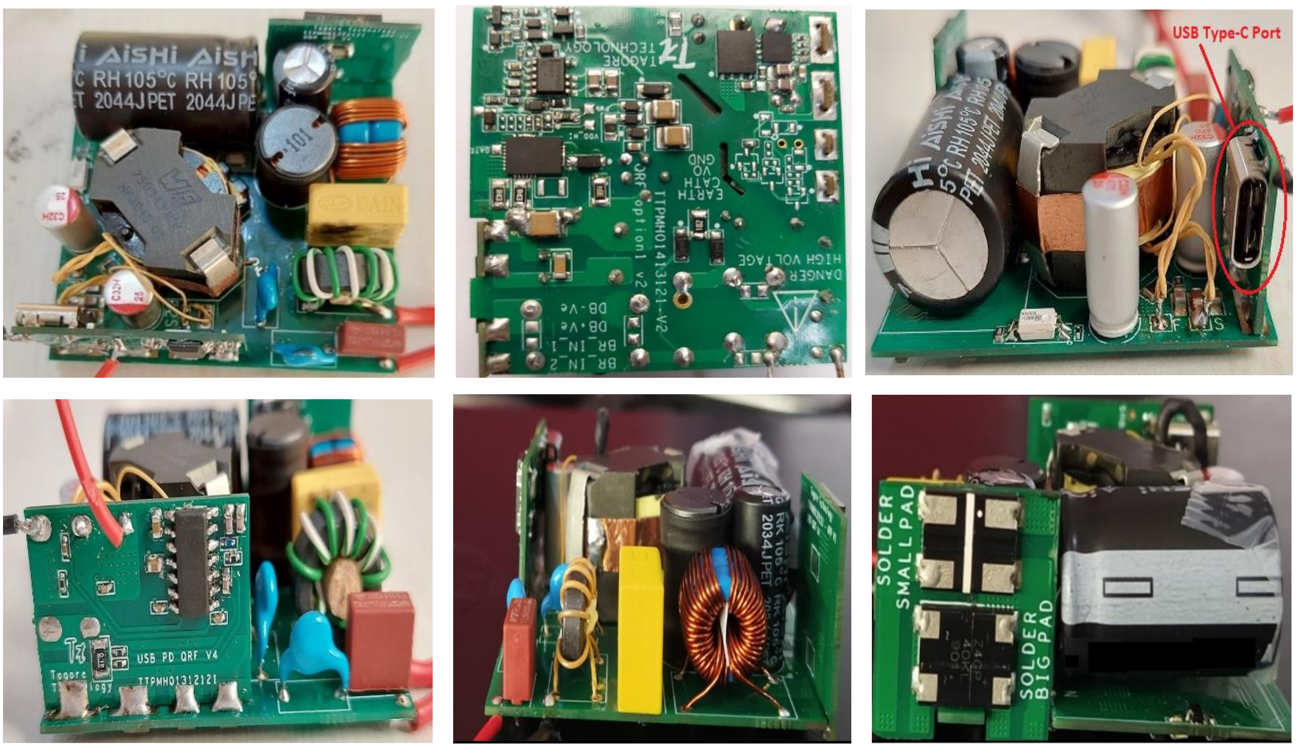


Figure 1: Three-dimensional views of Tagore's 45W USB PD Charger EVB (Volume: 49 cc).

2 EVB DETAILS AND ITS OPERATION

The EVB is a robust, isolated, QRF AC-DC converter. It uses Tagore Technology's Superior GaN FET TP44400SG and controlled by onsemi's controller IC NCP1342. The secondary side rectification is achieved through synchronous rectification using Low-Voltage (LV) MOSFETs and onsemi's synchronous rectifier controller IC NCP43080DMN. The peak efficiency obtained is > 93.5 %, which leads to very low power losses within the board and helps keep the GaN FET temperature low without using any heatsink. The EVB is designed to deliver 45W (max) at 20 VDC output. In addition, there are programmable outputs of 5V, 9V, 15V for which the maximum output current is 3A. The EVB works with universal AC input voltage and frequency ranges (90V – 265V, 50/60 Hz).

This EVB uses the same PCB, which is used in Tagore's 65W EVB *TP44200SG-QRF45-EVB*. Most of the components BOM (except for the transformer, GaN FET, electrolytic capacitors and few other components) are also same in both the EVBs. However, for optimized design, user can develop a new PCB.

2.1 BOARD IMAGES AND DIMENSIONS

Different images of the EVB are shown in Fig. 1. It has a dimension of 4.9 cm × 4.9 cm × 2.1 cm (L x W x H), and a volume of 49 cc.

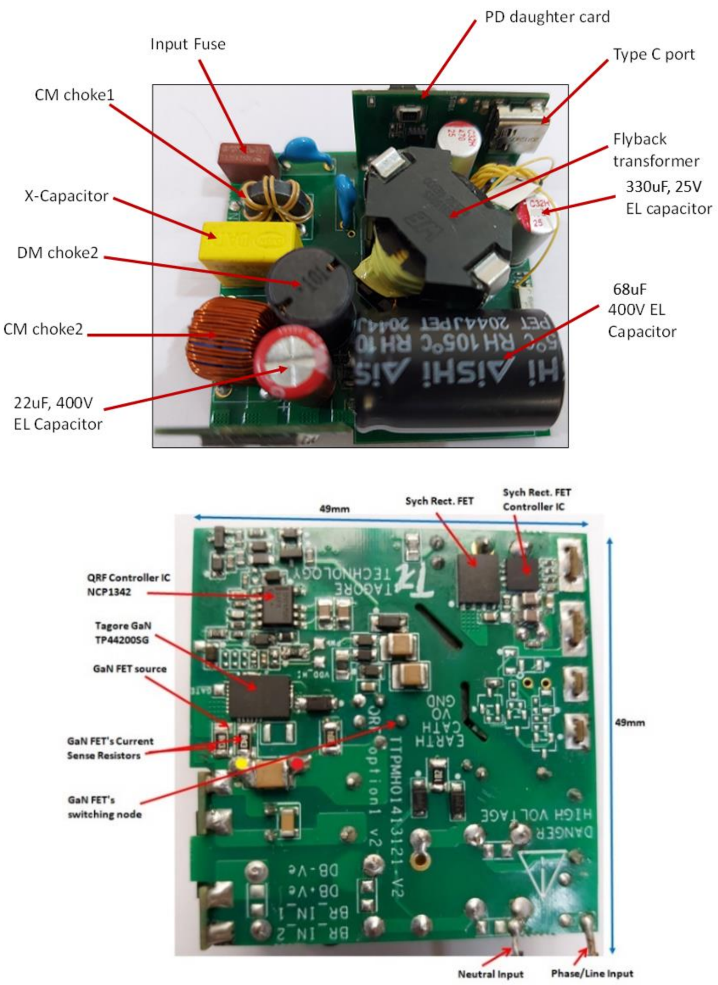


Figure 2: Top and Bottom views of the EVB with dimensions and component markups.

2.2 COMPONENT MARKUPS

The top and bottom side images of the EVB, showing major components, are shown in Fig. 2.

2.3 TOPOLOGY AND FUNCTIONAL BLOCK DIAGRAM

The EVB uses a Quasi Resonant Flyback (QRF) converter topology as shown in Fig. 3. At the input stage, there is an EMI filter circuit, which is followed by a diode bridge rectifier. The latter rectifies the AC input voltage and creates the necessary DC bus voltage for the Flyback converter. The Tagore Technology's Superior GaN FET Q_1 (TP44400SG) serves as the main switching device. Onsemi's QRF controller IC NCP1342 releases the required PWM pulses for the GaN. The secondary side comprises of a synchronous rectifier, which uses a low-voltage Si MOSFET, and onsemi's synch. FET controller IC NCP43080. At the output stage, there is series-pass MOSFET Q_4, controlled by the PD controller IC FUSB3307.

The QRF controller IC generates its initial/startup bias power from the AC supply to release the first set of PWM pulses to the GaN FET. As the GaN FET starts switching, the transformer gets energized, and its bias winding strengthens the controller bias supply.

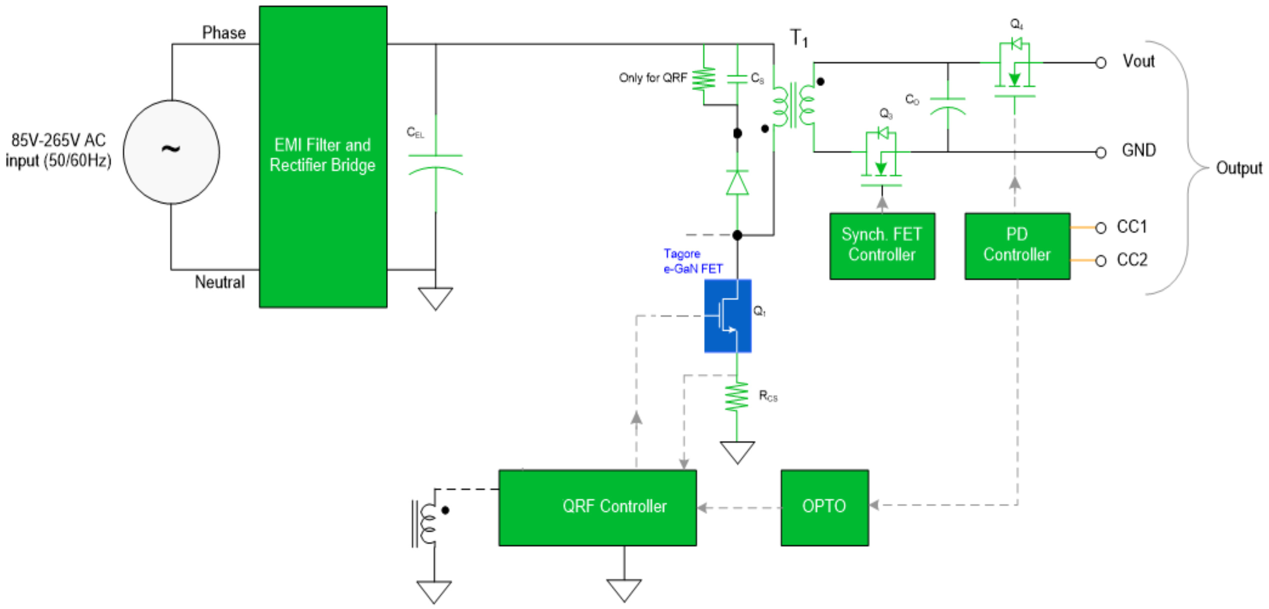


Figure 3: Functional block diagram of the 45W GaN EVB.

2.4 SPECIFICATIONS

The key system specifications are given in Table 1.

Table 1: Key system specifications

PARAMETER	TEST CONDITION	MIN	NOM	MAX	UNIT
INPUT CHARACTERISTICS					
V_{IN} Input line voltage (RMS)		90	115/230	265	V
f_{LINE} Input line frequency		47	50/60	63	Hz
P_{STBY} Input power at no-load	V_{IN} = 115/230 V_{RMS}, I_{OUT} = 0A		40/65		mW
OUTPUT CHARACTERISTICS					
V_{OUT} Output voltage (USB-C PD) for V_{IN} = 90 to 265V RMS	I_{OUT} = 0 to 2.25 A		20.0		V
	I_{OUT} = 0 to 3.00 A		15.0		
			9.0		
			5.0		
I_{OUT} Rated current at full load for V_{IN} = 90V to 265V RMS	V_{OUT} = 20.0V		2.25		A
	V_{OUT} = 5V or 9V or 15V		3		
V_{OUT_PP} Ripple in the output voltage for V_{IN} = 115V/230V RMS	V_{OUT} = 20V, I_{OUT} = 0 to 2.25 A		100	115	mVpp
	V_{OUT} = 15V, I_{OUT} = 0 to 3A		90	95	
	V_{OUT} = 9V, I_{OUT} = 0 to 3A		80	85	
	V_{OUT} = 5V, I_{OUT} = 0 to 3A		70	75	
P_{OUT_OPP} Over-power protection threshold	V_{IN} = 90V to 265V RMS		50		W
SYSTEMS CHARACTERISTICS					
η Peak efficiency V_{IN} = 90V to 265V RMS	V_{OUT} = 20 V		93.1/92.2		%
	V_{OUT} = 15 V		93.0/91.9		
	V_{OUT} = 9V		92.6/91.1		
	V_{OUT} = 5V		91.1/89.1		
η 4-Point Average efficiency V_{IN} = 90V to 265V RMS	V_{OUT} = 20V (CoC Tier 2 - 89.0%)		92.6/92.1		%
	V_{OUT} = 15 V (CoC Tier 2 - 88.9%)		92.4/91.3		
	V_{OUT} = 9V (CoC Tier 2 - 87.3%)		92.1/90.5		
	V_{OUT} = 5V (CoC Tier 2 - 81.8%)		90.6/88.0		
η Efficiency at 10% load V_{IN} = 90V to 265V RMS	V_{OUT} = 20 V (CoC Tier 2 - 79.0%)		90.1/88.6		%
	V_{OUT} = 15 V (CoC Tier 2. 78.9%)		89.9/88.0		
	V_{OUT} = 9V (CoC Tier 2. 77.3%)		86.5/82.6		
	V_{OUT} = 5V (CoC Tier 2. 72.5%)		86.0/82.7		

3 CONNECTIONS AND START-UP PROCEDURE

This section describes a detailed connection diagram and start-up procedure for the EVB.

Before making the electrical connections, turn off the AC input supply switch. Note that the DC bus electrolytic capacitor (400V rated) might be charged at high voltage. Make sure, it is discharged before touching the PCB. The positive and negative terminals of the HV electrolytic capacitor are marked by Red and Yellow colored dots, respectively, in Fig. 2. A bleeder resistor can be connected between these points to discharge the DC bus voltage.

In order to complete all the electrical connections between the EVB, and the AC input and load, please refer to the EVB's top and bottom views as presented in Fig. 2. The AC input terminals are marked at the bottom right corner of the PCB shown in Fig. 2. The DC output is taken from the USB C port located at one end of the daughter card as shown in Fig. 2 (top right).

3.1 OPERATING PROCEDURE

The operating procedure of the Eval board is explained as follows:

(a) Connect the EVB's AC Input terminals to a suitable AC source (90 – 265 V RMS, 50/60 Hz).

(b) Connect the USB PD sink load through Type-C receptacle.

(c) Connect all the necessary instruments to the EVB such as voltmeter, ammeter, DSO and power analyzer.

(d) Turn on the AC supply gradually from 0 to 90 V. Check the output voltage to be present at the type C port.

(e) Increase the input voltage to any desired value as per the test specification/requirement.

(f) Output voltage (5V, 9V, 15V or 20 V) can be negotiated between the EVB and PD sink load.

(g) Set load current between 0 – 3A for 5V, 9V, 15V outputs, and 0 – 2.25 A for 20 V output.

(h) A typical test setup used at Tagore Technology's lab is shown in Fig. 4.

Figure 4: 45 W QRF EVB test setup.

4 EXPERIMENTAL RESULTS

The QRF Eval board is tested at different input and output voltages and power levels. Various switching waveforms are shown in this section.

4.1 SWITCHING WAVEFORMS

The QRF converter works in the Discontinuous Conduction Mode (DCM). The controller NCP1342 enables QR valley-switching during turn on instant of the GaN FET. It ensures the switching losses due to sudden discharge of the switch-node capacitance through the GaN FET during turn on to be low. At full load, the GaN FET turns on at the first valley of the DCM ringing. At lighter loads, the GaN turns on at the higher valleys such as, second, third, fourth etc. The corresponding experimental switching waveforms as presented in Figs. 5 and 6.

The GaN FET current (*Blue traces*) is measured as the voltage drop across a 0.32 Ω current sense resistor. The other switching waveforms (Fig. 5) indicate that the GaN FET turns on at the DCM valleys of the switch node voltage. The overshoots observed in the switch node voltage is due to the leakage inductance of the transformer. It is comparatively more at low input voltage due to higher transformer current and leakage energy. The switching voltage spikes can be reduced further by allowing more dissipation in the snubber.

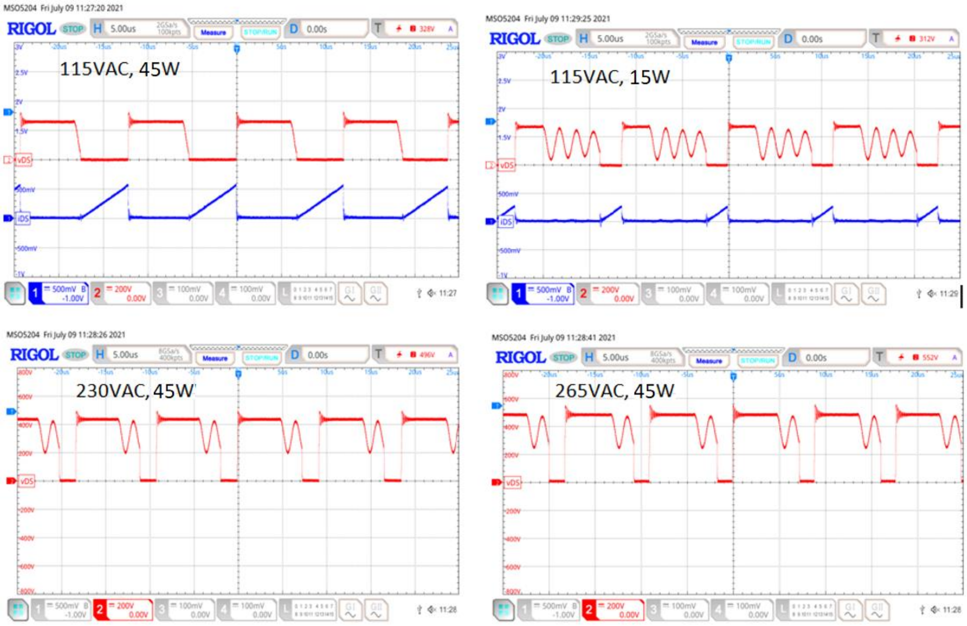


Figure 5: GaN FET switch node voltage waveforms at 20V output for different input voltages.

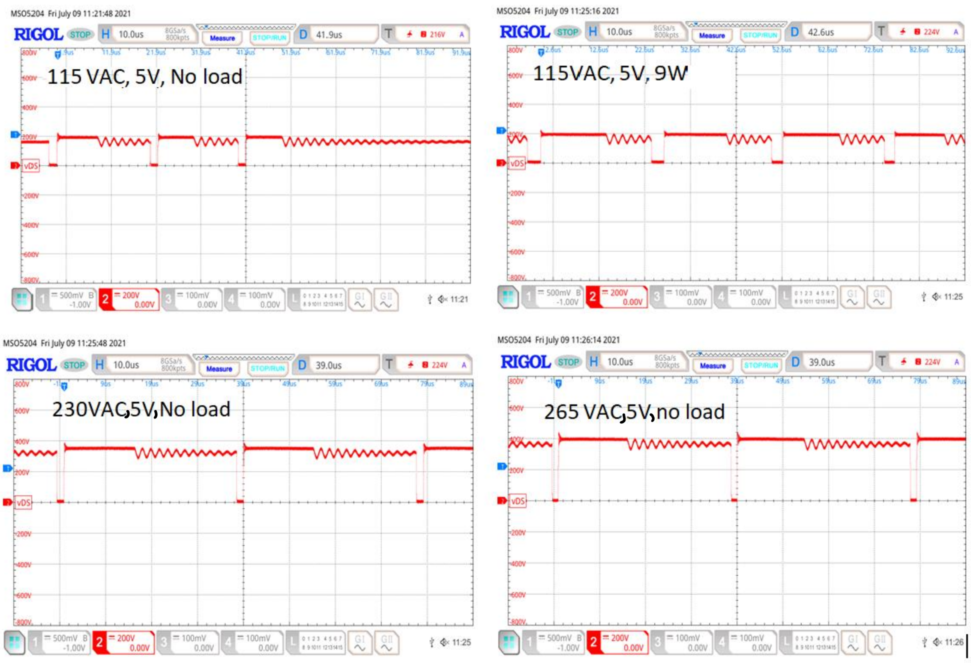


Figure 6: GaN FET switch node voltage waveforms at 5V output for different input voltages.

4.2 LOAD TRANSIENT WAVEFORMS

The EVB is tested for its load dynamic response. The load current is suddenly changed between 0.3A to 2.25A, and the corresponding changes in the output voltage is observed. This is presented in Fig. 7. The dip/swell observed in the output voltage (*Orange trace*) is less than 0.5V.

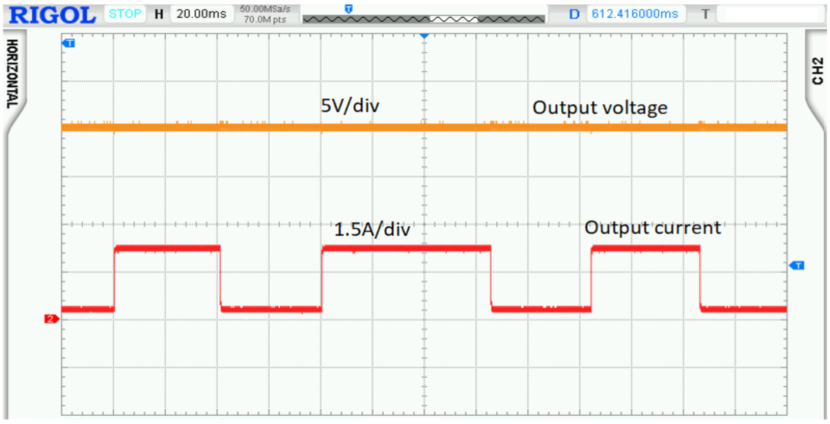
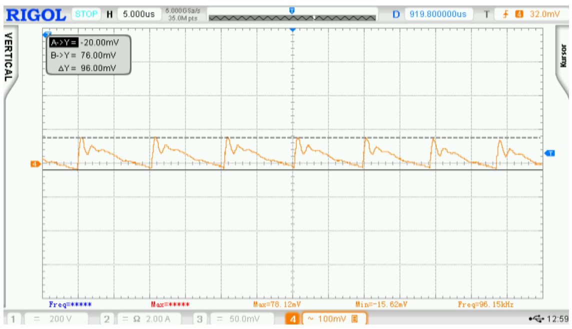


Figure 7: Load dynamic response of the EVB at 115 VAC and 20V Output.

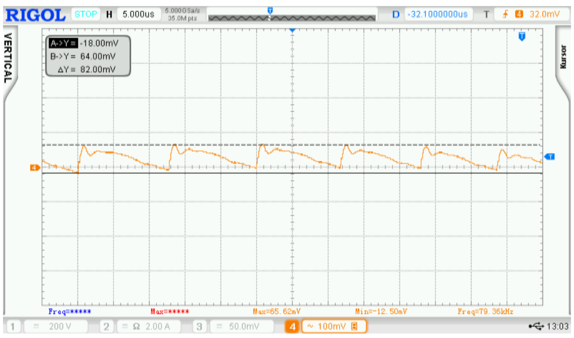
4.3 OUTPUT VOLTAGE RIPPLE (ΔV_O)

The 45W EVB is tested to measure its output voltage ripple at all output voltage levels. These are presented in Fig. 8. The measured peak-to-peak ripple ΔV_O at no-load is less than 120 mV. The ripple voltage can further be reduced by adding more capacitors at the output.

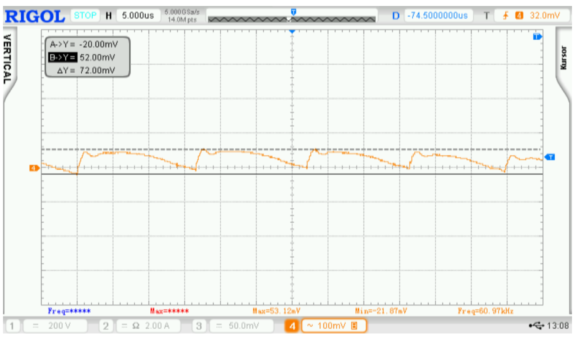
Peak-to-Peak Ripple 118mV at 20V output.



Peak-to-Peak Ripple 96mV at 15V output.



Peak-to-Peak Ripple 82mV at 9V output.



Peak-to-Peak Ripple 72mV at 5V output.

Figure 8: Measured peak-to-peak ripple voltage at the output of the EVB.

5 PERFORMANCE DATA

5.1 EFFICIENCY DATA

This section presents different efficiency plots of the EVB. The input-to-output power conversion efficiencies versus load current at different output voltages and two input voltages (115 Vac, 230 Vac) are shown in Fig. 9.

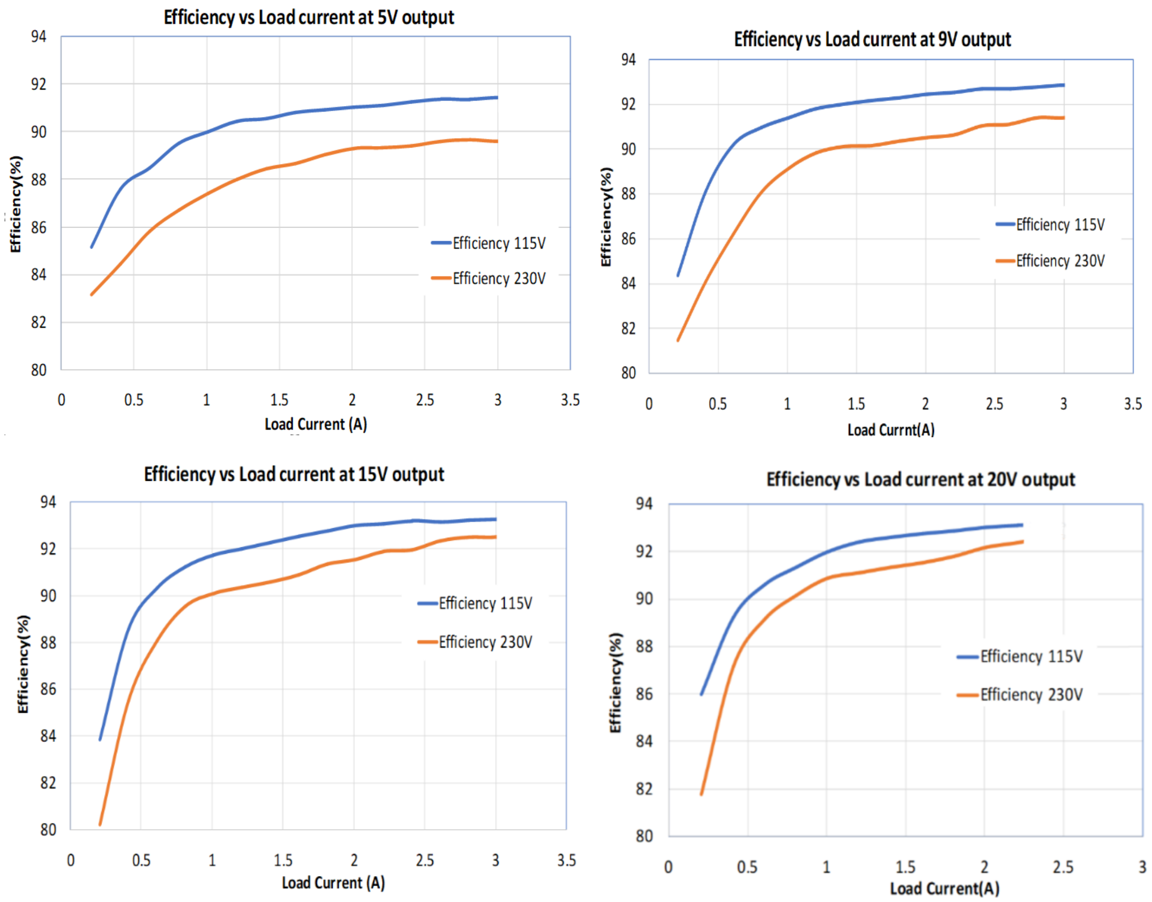


Figure 9: Efficiency plots of the EVB at different input and output voltage conditions.

5.2 FOUR-POINT AVERAGE EFFICIENCY

USB Type-C chargers comply with different Efficiency Standards such as, CoC Tier-2 and DoE Level 6. In both standards, the charger's four-point (25%, 50%, 75% and 100% loads) efficiencies are compared against their corresponding reference values. In addition, CoC Tier2 standard also looks for efficiency number at 10% load. This section presents the EVB's four-point average efficiency data in both tabular form as well as in plotted form. A comparison w.r.t the CoC Tier2 and DoE Level 6 is given.

The Four-point average efficiency table is presented in Table-2, while its corresponding plots are given in Fig. 10. The efficiencies at 10% load, as required by CoC Tier-2, is presented in Table-3 and Fig. 11. In all the cases, the EVB efficiency is higher than the reference values.

Table-2: Four-Point Average Efficiency.

Tagore 45W EVB			Standards	
Vout (V)	**115VAC**	**230VAC**	**CoC Tier-2**	**DoE Level-6**
5	90.1	88.2	81.8	81.25
9	92.1	90.05	87.3	86.3
15	92.3	91.1	88.9	87.7
20	92.3	91.5	89	88

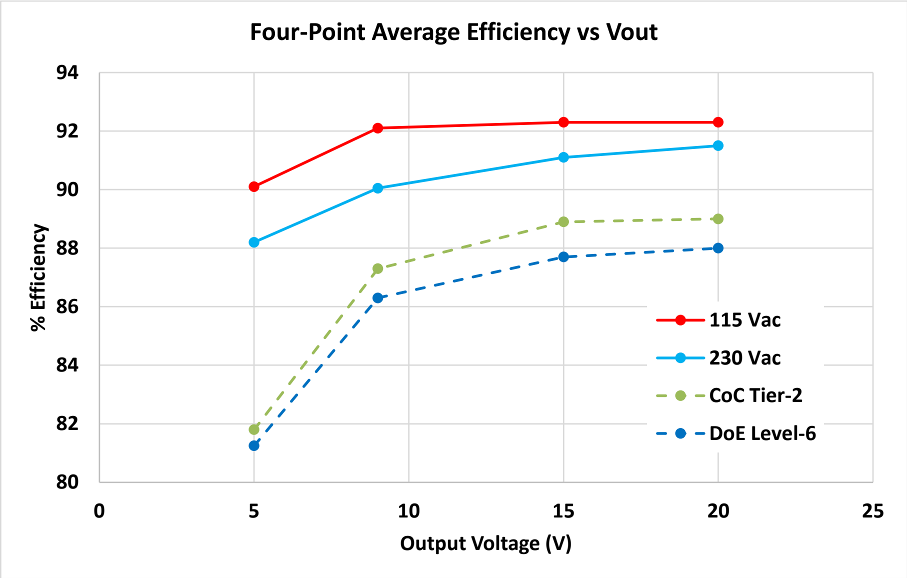


Figure 10: Four-Point average efficiency w.r.t. CoC Tier2 and DoE Level6 standards.

Table-3: Efficiency at 10% Load w.r.t. CoC Tier-2 Reference.

Tagore 65W EVB			Standard
Vout(V)	115 VAC	230 VAC	CoC Tier2
5	86	83.9	72.5
9	86.5	84	77.3
15	87.4	85.1	78.9
20	88.3	87	79

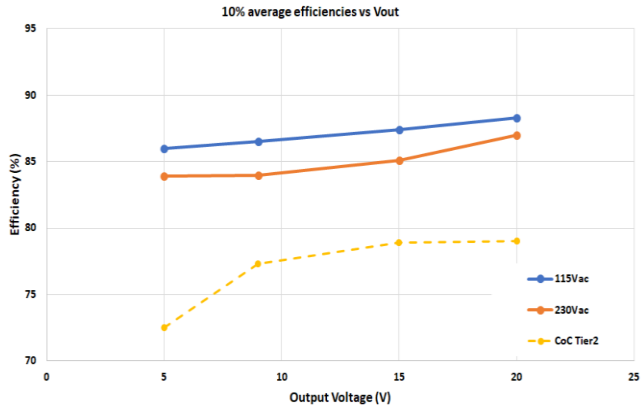


Figure 11: EVB efficiencies at 10% load for different output voltages w.r.t. CoC Tier-2 reference.

5.3 LOAD REGULATION

This test shows the effect of load changes on the steady state output voltage. The test results, shown in Fig. 12, indicate that the output voltage remains steady for the entire range of load variations.

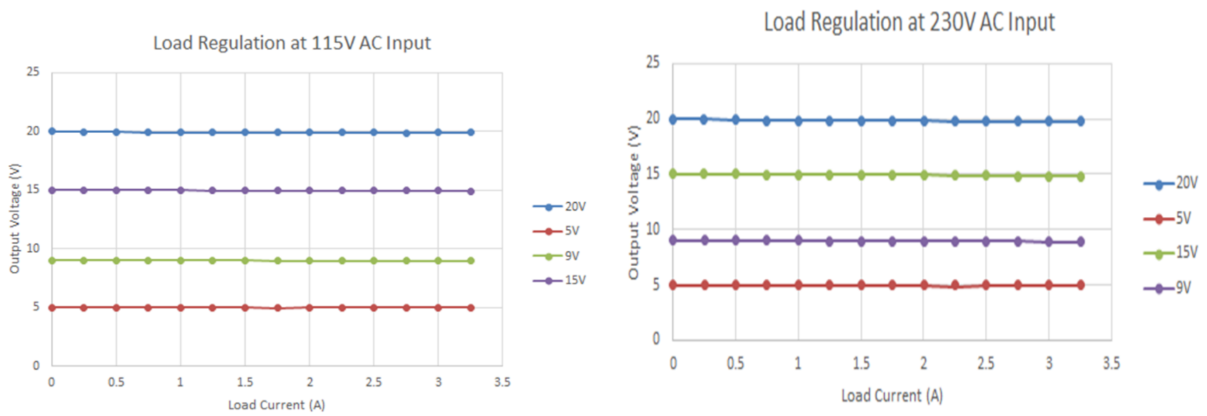


Figure 12: Load regulation data of the EVB at 115Vac (left) and 230Vac (right).

5.4 NO LOAD POWER

The Tagore's EVB meets the no load input power standard as specified in CoC Tier-2 and DoE Level-6 standards. This is shown in Table 4.

Table 4: No load input power w.r.t. different standards.

Vin (AC)	Input Power Loss	CoC V5 TIER 2	DOE_VI
115V	45 mW	150 mW	210 mW
230V	65 mW		

5.5 THERMAL DATA

This section presents the thermal performance of the EVB at room temperature of 25 ºC. The EVB is tested both in open case as well as in closed case environments without using any fan. The maximum temperature rise happens at minimum AC input voltage (90 Vac) and maximum output power of 45W at 20Vdc output.

Open case Test

The EVB is left running (open case) for half-an-hour to stabilize the temperatures at different components before taking the thermal data. The final temperatures of some the critical components are tabulated in Table-5. The thermal images w.r.t. the board pictures are presented in Fig. 13 for 115 Vac input and 45 W output.

It should be noted that there is no heatsink attached to the GaN FET. All the heat generated by the GaN is dissipated in the PCB. In the final product, it is recommended to use some heatsink or heat spreader to absorb some of the heat generated by the GaN for its better performance.

Table-5: Worst case temperature rise data at 115 Vac input (Open case)

Component	Transformer	Bridge Rectifier	Tagore GaN FET	Primary RCD Snubber	SR FET
Max Temp (^{o}C)	59	57	55	52	63

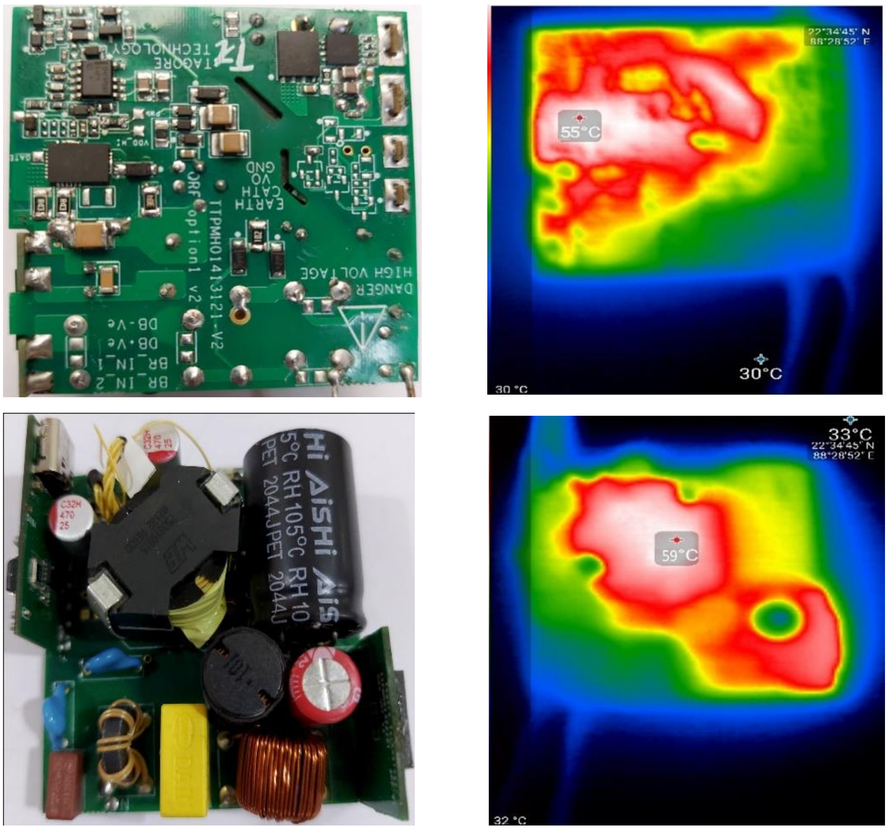


Figure 13: Thermal scan data of the EVB at rated output power and 115 Vac.

Closed case thermal test

The EVB is placed inside a 3D printed closed box of dimensions 80mm (L) x 80mm (W) x 40mm (H) as shown in Fig. 14. Thermocouple probes are fixed on the key component/parts, whose temperatures need to be monitored. All the input output cables/leads and thermocouple probes are brought out of the box as shown. The unit is run for 45 mins at 45 W output and different output voltages. The temperature rises to different critical components at the end of 45 mins are tabulated in Table-6.

Although, there is no additional thermal management material (such as thermal pad, extra heatsink and thermal glue) used; very little silicon glue, however, is used to fix the 68uF Electrolytic Capacitor on the PCB as it is placed horizontally. It helps absorb some of the heat generated by the GaN and allow it to be little cool.

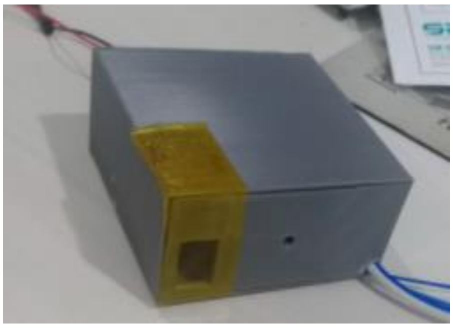
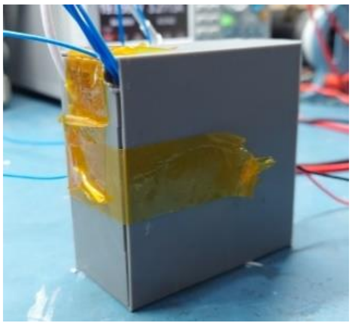



Figure 14: Closed box thermal test of the EVB.

Table-6: Worst case temperature rise data (closed case)

Vin = 115Vac; Vout = 20V; Iout= 2.25A)					
	Temperatures (°C)				
Time (Min)	GaN FET	DBR	Transformer core	Synch. FET	Output Power (W)
0	26.2	26.2	26.2	26.2	45
10	60.6	55.5	65.1	54.32	
20	76	69	78.7	66.04	
30	81.1	73.9	84.2	71.6	
45	83.9	76.6	86.3	73.45	

Vin = 230Vac; Vout = 20V; Iout = 2.25A)					
	Temperatures (°C)				
Time (Min)	GaN FET	DBR	Transformer core	Synch. FET	Output Power (W)
0	26.20	26.20	26.20	26.20	45
10	61.45	50.28	65.20	54.10	
20	78.03	65.65	78.63	66.78	
30	84.48	71.20	84.10	72.70	
45	86.28	74.50	87.70	75.70	

Vin = 265Vac; Vout = 20V; Iout = 2.25A)					
	Temperatures (°C)				
Time (Min)	GaN FET	DBR	Transformer core	Synch. FET	Output Power (W)
0	26.20	26.20	26.20	26.20	45
10	62.13	48.33	66.03	54.18	
20	78.25	62.20	80.13	69.93	
30	85.53	68.20	86.58	75.78	
45	88.08	70.60	89.65	79.08	

5.6 EMI

Tagore's 45W QRF EVB complies with FCC class B conducted and radiated EMI standards EN55022 and EN55032, respectively. Tagore has in house facility to measure the Conducted EMI performance of its reference design boards before going to the external certified lab.

In this EVB, there are two Common Mode (CM) chokes CM1 and CM2, which help attenuate the CM noise. The bridge rectifier rectifies the AC line voltage and provides a full wave rectified DC across the filter capacitor. The differential mode choke, placed on the DC bus as a PI filter, and the X2 capacitor, connected externally across the AC side of the bridge rectifier, are used to mitigate the Differential Mode (DM) EMI noise. The Conducted and Radiated EMI scans, obtained from external certified lab at different loads, are shown in Figs. 15 and 16.

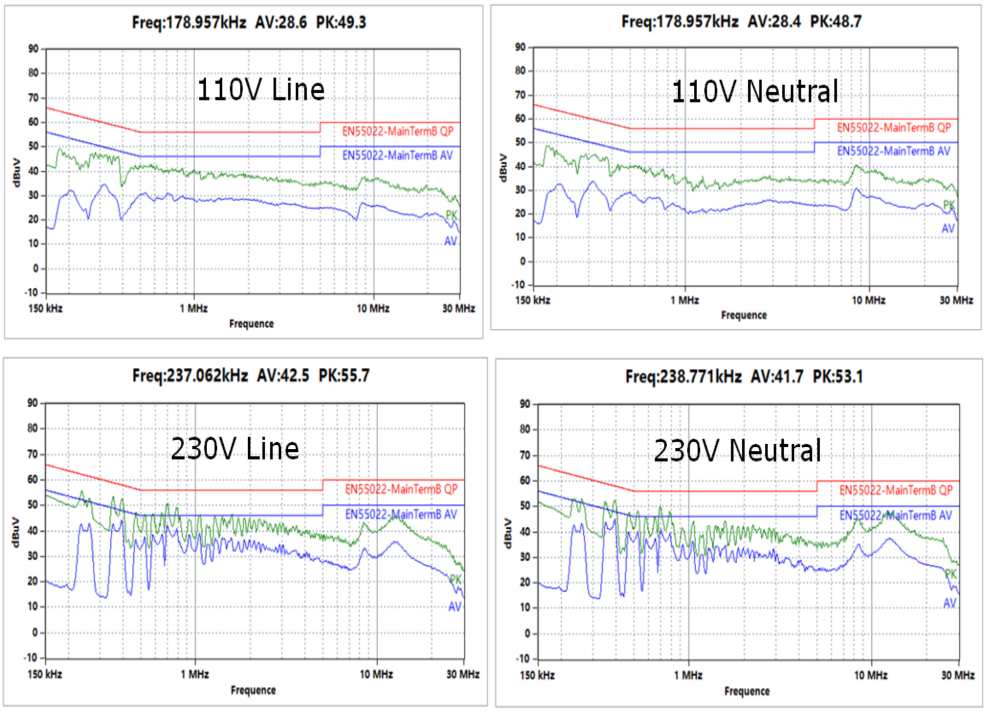
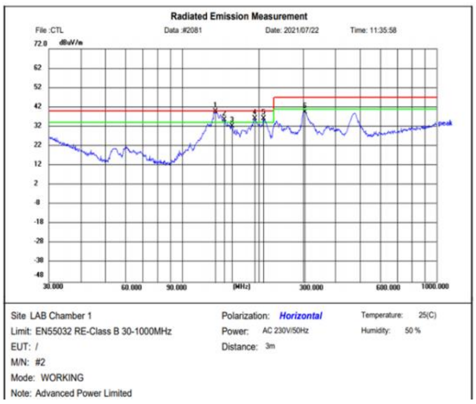
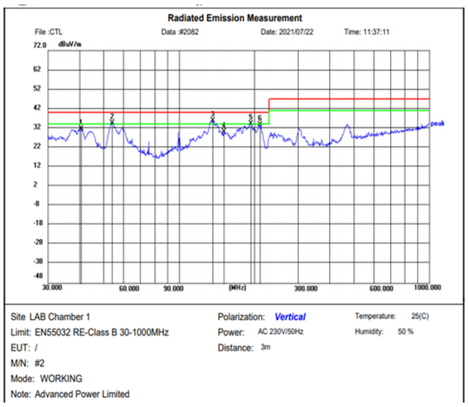


Figure 15: Conducted EMI test results of the EVB.

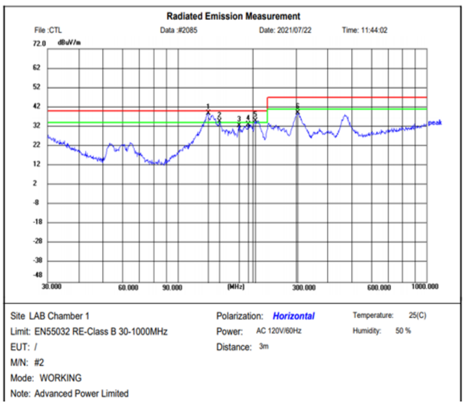
230V, 50Hz, 45W Horizontal



230V, 50Hz, 45W Vertical



120V, 60Hz, 45W Horizontal



120V, 60Hz, 45W Vertical

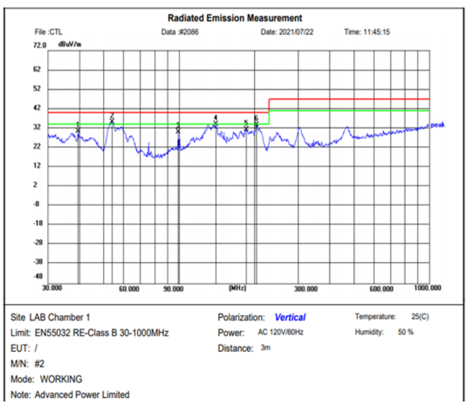


Figure 16: Radiated EMI test results of the EVB at different input voltages.

6 PCB SCHEMATIC

This section presents the PCB schematics for the EVB. The EVB has one mother board and two daughter boards. The mother board contains the transformer primary side components, the QRF controller, and the transformer's secondary side components such as the Synchronous FET and its controller. The first daughter board contains the PD controller and the output series pass FET. The AC input cable is terminated to the mother board, while the DC output power is taken out from the USB Type-C connector, soldered on the first daughter board. The two diode bridges are mounted on another small daughter board. The mother board schematic is presented in Figs. 17, 18 and 19, while the daughter board PCBs are shown in Figs. 20 and 21.

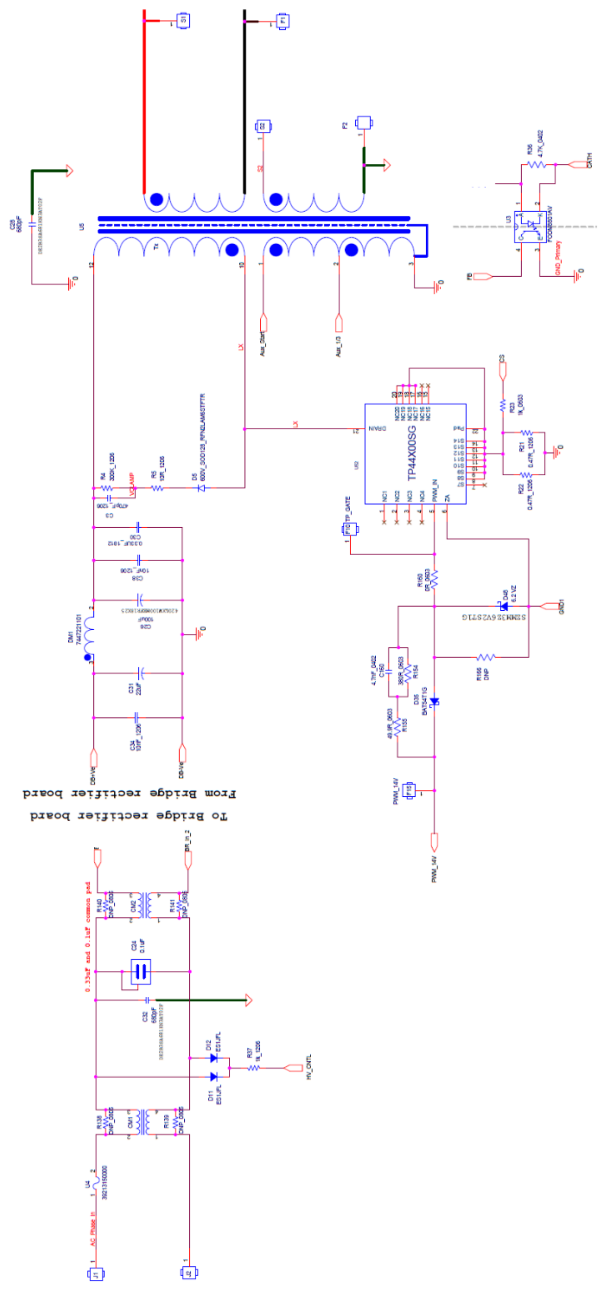


Figure 17: Schematic - Mother Board – section 1

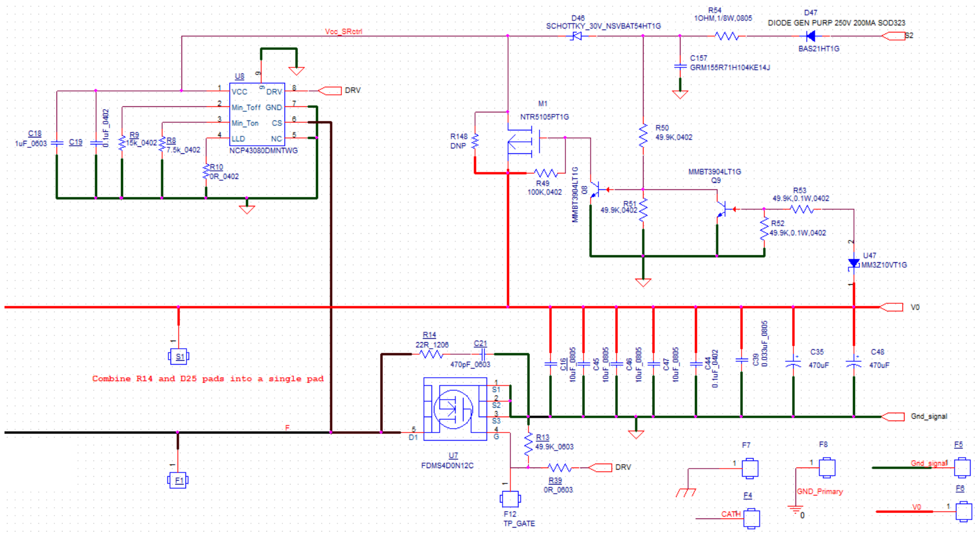


Figure 18: Schematic – Mother Board – section 2.

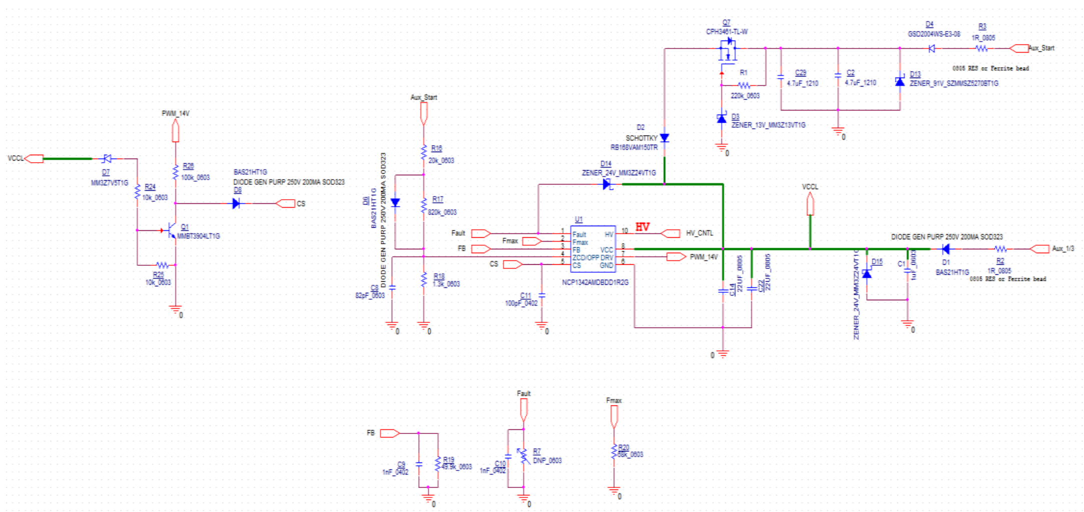


Figure 19: Schematic – Mother Board – section 3.

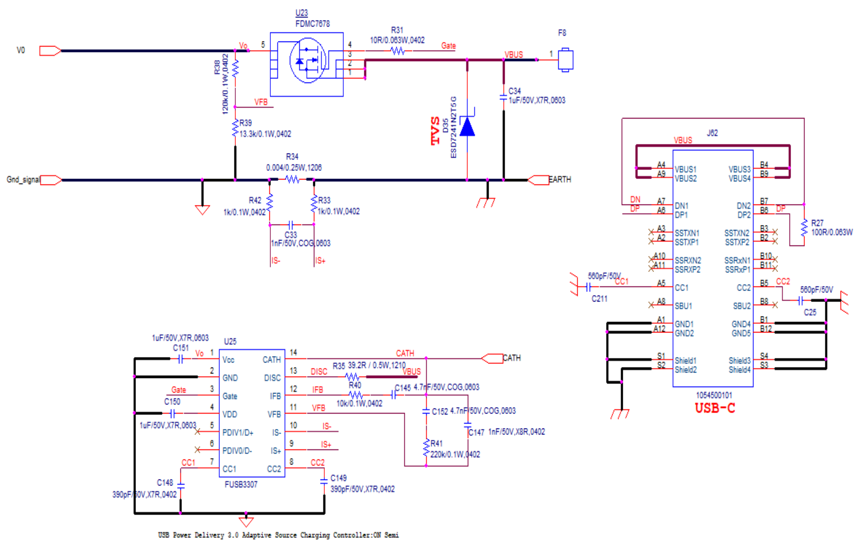


Figure 20: Schematic - Daughter Board (PD controller).

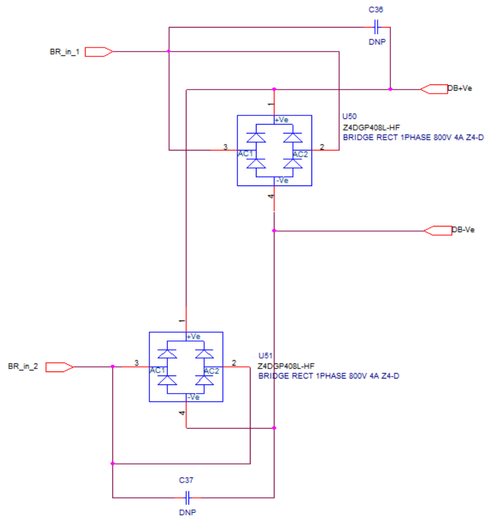


Figure 21: Schematic – Diode Bridge Rectifier Board.

7 PCB LAYOUT AND ASSEMBLY

The evaluation board has been realized on a 4-layer PCB.

7.1 PCB LAYOUT

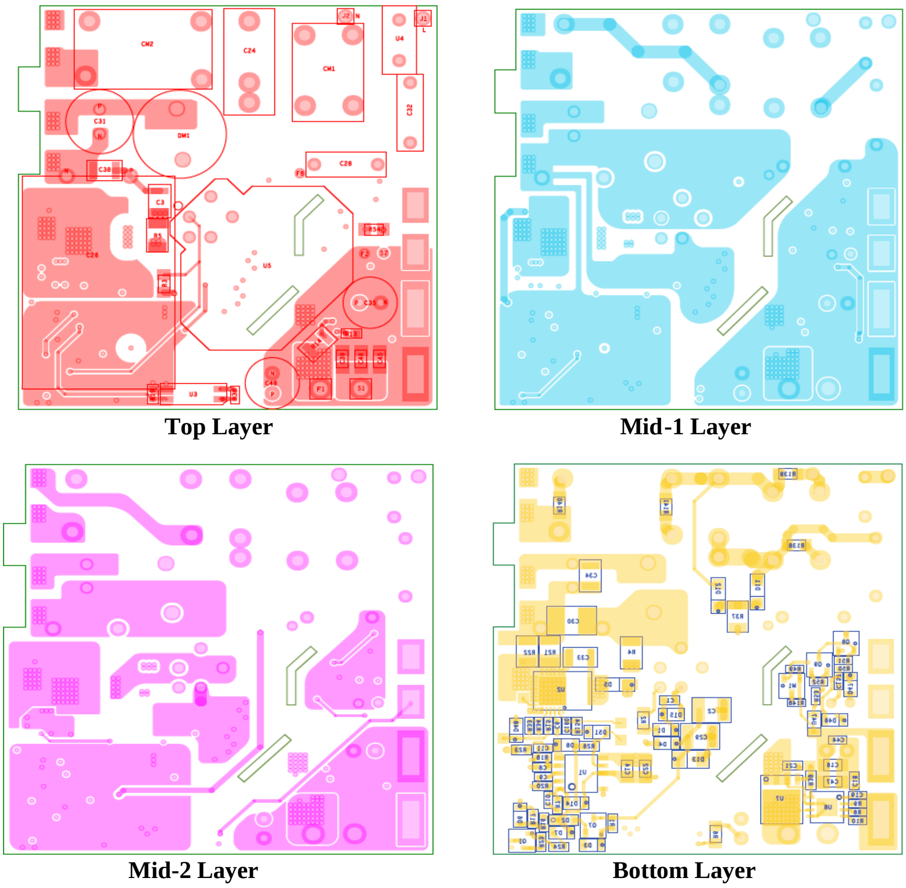
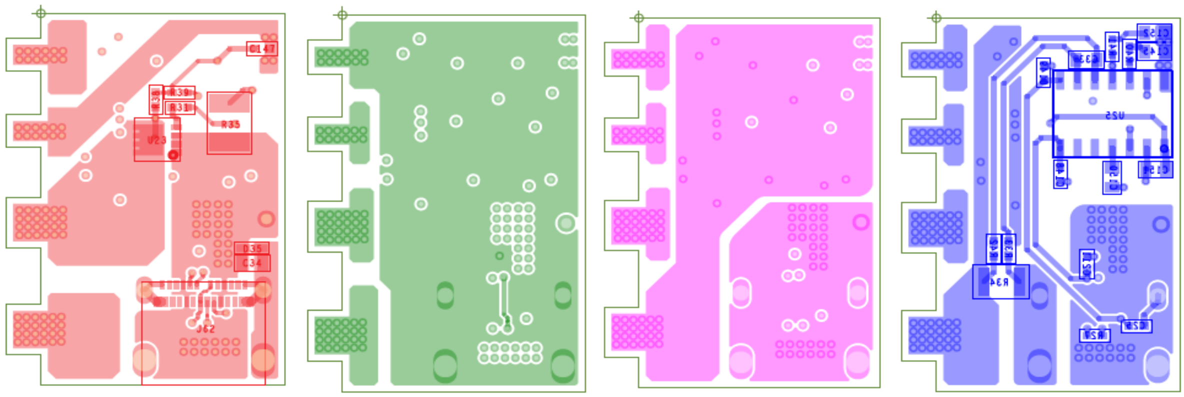


Figure 22: Layout details for the different layers of the Mother Board.

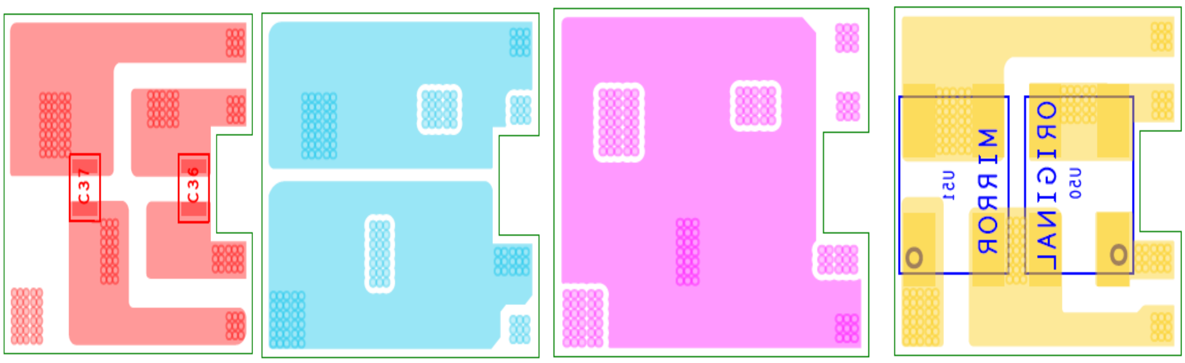
Daughter board-1 (PD controller) PCB layout details:



Top Layer Mid-1 Layer Mid-2 Layer Bottom Layer

Figure 23: Layout details for the different layers of the Daughter Board-1 (PD controller card).

Daughter board-2 (Diode bridges) PCB layout details:



Top Layer Mid-1 Layer Mid-2 Layer Bottom Layer

Figure 24: Layout details for the different layers of the Diode Bridge Rectifier Board.

7.2 BILL OF MATERIALS

Bill of Materials - Mother Board						
Item	Quantity	PCB Reference	Part Description	Manufacturer	Manufacturer PN	Package
1	1	CM1	22uH, 1.5A, 40mOhm		Custom	Custom
2	1	CM2	3.5mH. 1.5A, 90mOhm		Custom	Custom
3	1	C1	CAP CER 1µF 25V X7R 0603	Samsung Electronics	CL10B105KA8NNNC	0603
4	1	C18	CAP CER 1µF 25V X7R 0604	Samsung Electronics	CL10B105KA8NNNC	0603
5	1	C2	CAP CER 4.7µF 100V X7S 1210	Murata Electronics	GCM32DC72A475KE02L	1210
6	1	C29	CAP CER 4.7µF 100V X7S 1210	Murata Electronics	GCM32DC72A475KE02L	1210
7	1	C3	CAP CER 470pF 630V C0G 1206	TDK Corporation	C3216C0G2J471K085AA	1206
8	1	C8	CAP CER 82pF 50V C0G/NP0 0603	KEMET	C0603C820J5GACTU	0603
9	1	C9	CAP CER 1000pF 50V X7R 0402	Wurth Eectronics	885012205061	0402
10	1	C10	CAP CER 1000pF 50V X7R 0402	Wurth Eectronics	885012205061	0402
11	1	C11	CAP CER 100pF 50V C0G/NP0 0402	Wurth Eectronics	885012005061	0402
12	1	C14	MLCC 22µF 25V X5R 0805	Samsung Electro-Mechanics	CL21A226MAYNNNE	0805
13	1	C22	MLCC 22µF 25V X5R 0805	Samsung Electro-Mechanics	CL21A226MAYNNNE	0805
14	1	C16	MLCC 10 µF 25V X7S 0805	TDK Corporation	C2012X7S1E106K125AE	0805
15	1	C45	MLCC 10 µF 25V X7S 0805	TDK Corporation	C2012X7S1E106K125AE	0805
16	1	C46	MLCC 10 µF 25V X7S 0805	TDK Corporation	C2012X7S1E106K125AE	0805
17	1	C47	MLCC 10 µF 25V X7S 0805	TDK Corporation	C2012X7S1E106K125AE	0805
18	1	C19	CAP CER 100nF 50V X7R 0402	Wurth Eectronics	885012205086	0402
19	1	C44	CAP CER 100nF 50V X7R 0402	Wurth Eectronics	885012205086	0402
20	1	C21	CAP CER 470pF 250V C0G/NP0 0603	Wurth Eectronics	885342006005	0603
21	1	C24	Film Capacitor, X2	Custom	Custom	Through Hole
22	1	C26	68uF, 400V. 16x25mm	Aishi Capacitors	Custom	Through Hole
23	1	C28	CAP CER 680pF 250V RADIAL	Murata Electronics	DE2B3SA681KN3AT02F	Through Hole
24	1	C32	CAP CER 680pF 250V RADIAL	Murata Electronics	DE2B3SA681KN3AT02F	Through Hole
25	1	C30	CAP CER 0.33µF 500V X7R 1812	KEMET	C1812C334MCRAC7800	1812

Bill of Materials - Mother Board						
Item	Quantity	PCB Reference	Part Description	Manufacturer	Manufacturer PN	Package
26	1	C31	22uF ,400V,8X16mm	Wurth Eectronics	860021374027	Through Hole
27	1	C34	10nF_1206 (DNP)	-	885342208012	1206
28	1	C38	10nF_1206 (DNP)	-	885342208012	1206
29	1	C35	CAP POLYMER 470uF, 25V, 6.3x14mm, RIPPLE 3.4A	Aishi Capacitors	SPF1EM471E14O00RA	Through Hole
30	1	C48	CAP POLYMER 470uF, 25V, 6.3x14mm, RIPPLE 3.4A	Aishi Capacitors	SPF1EM471E14O00RA	Through Hole
31	1	C36	CAP DNP	DNP	DNP	1206
32	1	C37	CAP DNP	DNP	DNP	1206
33	1	C39	CAP CER 0.033µF 100V X7R 0805	Wurth Eectronics	885012207125	0805
34	1	C157	CAP CER 0.1µF 50V X7R 0402	Murata Electronics	GRM155R71H104KE14J	0402
35	1	C160	CAP CER 4700 pF 50V X8L 0402	Murata Electronics	GCM155L81H472KA37J	0402
36	1	DM1	DM Choke 100µH 2.45A 100mOhm	Wurth Eectronics	7447221101	Through Hole
37	1	D1	DIODE GEN PURP 250V 200mA	onsemi	BAS21HT1G	SOD-323
38	1	D6	DIODE GEN PURP 250V 200mA	onsemi	BAS21HT1G	SOD-323
39	1	D8	DIODE GEN PURP 250V 200mA	onsemi	BAS21HT1G	SOD-323
40	1	D47	DIODE GEN PURP 250V 200mA	onsemi	BAS21HT1G	SOD-323
41	1	D2	Diode Schottky 150 V 1A	Rohm Semiconductor	RB168VAM150TR	SOD-323HE
42	1	D3	DIODE ZENER 13V 300mW	onsemi	MM3Z13VT1G	SOD-323
43	1	D4	DIODE GEN PURP 240V 225mA	Vishay General Semiconductor	GSD2004WS-E3-08	SOD-323
44	1	D5	DIODE GEN PURP 600V 1.5A	Rohm Semiconductor	RFN2LAM6STFTR	SOD-123w
45	1	D7	DIODE ZENER 7.5V 300mW	onsemi	MM3Z7V5T1G	SOD-323
46	1	D11	DIODE GEN PURP 600V 1A	onsemi	ES1JFL	SOD-123W
47	1	D12	DIODE GEN PURP 600V 1A	onsemi	ES1JFL	SOD-123W
48	1	D13	DIODE ZENER 91V 500mW	onsemi	SZMMSZ5270BT1G	SOD-123f
49	1	D14	DIODE ZENER 24V 300mW	onsemi	MM3Z24VT1G	SOD-323
50	1	D15	DIODE ZENER 24V 300mW	onsemi	MM3Z24VT1G	SOD-323
51	1	D35	DIODE SCHOTTKY 30V 200mA	onsemi	BAT54T1G	SOD-123
52	1	D46	DIODE SCHOTTKY 30V 200mA	onsemi	NSVBAT54HT1G	SOD-323
53	1	D48	DIODE ZENER 6.2V 300mW	onsemi	SZMM3Z6V2ST1G	SOD-323
54	1	M1	MOSFET P-CH 60V 196mA	onsemi	NTR5105PT1G	SOT-23-3
55	1	Q1	Transistor NPN 40V 200 mA 300 mW	onsemi	MMBT3904LT1G	SOT-23-3
56	1	Q8	Transistor NPN 40V 200 mA 300 mW	onsemi	MMBT3904LT1G	SOT-23-3
57	1	Q9	Transistor NPN 40V 200 mA 300 mW	onsemi	MMBT3904LT1G	SOT-23-3
58	1	Q7	MOSFET N-CH 250V 350mA	onsemi	CPH3461-TL-W	SOT-23-3
59	1	R1	RES 220 kOhms 5% 1/10W 0603	Stackpole Electronics Inc	RMCF0603JT220K	0603
60	1	R2	RES SMD 1 Ohms 1% 1/8W 0805	YAGEO	AC0805FR-071RL	0805
61	1	R3	RES SMD 1 Ohms1% 1/8W 0805	YAGEO	AC0805FR-071RL	0805
62	1	R4	RES SMD 300 kOhms 1% 1/4W 1206	Vishay Dale	CRCW1206300KFKEA	1206
63	1	R5	RES SMD 10 Ohms ±1% 0.75W 1206	Bourns Inc.	CMP1206AFX-10R0ELF	1206
64	1	R6	RES SMD 1 kOhms 5% 1/2W 0805	Panasonic Electronic Components	ERJ-P06J102V	0805
65	1	R7	RES DNP	DNP	DNP	0603
66	1	R8	RES SMD 7.5 kOhms 1% 1/10W 0402	Panasonic Electronic Components	ERJ-2RKF7501X	0402
67	1	R9	RES SMD 15 kOhms 1% 1/10W 0402	Panasonic Electronic Components	ERJ-2RKF1502X	0402
68	1	R10	RES SMD 0 Ohm 1/16W 0402	YAGEO	RC0402JR-070RP	0402
69	1	R13	RES SMD 49.9 kOhms 1% 1/10W 0603	Vishay Dale	CRCW060349K9FKEA	0603
70	1	R14	RES SMD 22 Ohms 1% 1/4W 1206	TE Connectivity	CRGCQ1206F22R	1206
71	1	R16	RES 20 kOhms 1% 1/10W 0603	Vishay Dale	CRCW060320K0FKEAC	0603
72	1	R17	RES SMD 820 kOhms 0.1% 1/16W 0603	TE Connectivity	CPF0603B820KE1	0603
73	1	R18	RES SMD 1.3 kOhms 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF1301V	0603
74	1	R19	RES 49.9 kOhms 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT49K9	0603
75	1	R20	RES SMD 68 kOhms 0.5% 1/16W 0603	Susumu	RR0816P-683-D	0603
76	1	R21	RES 0.47 Ohms 1% 1/4W 1206	Panasonic Electronic Components	ERJ-8RQFR47V	1206
77	1	R22	RES 0.47 Ohms 1% 1/4W 1206	Panasonic Electronic Components	ERJ-8RQFR47V	1206
78	1	R23	RES 1 kOhms 5% 1/10W 0603	YAGEO	RC0603JR-071KL	0603
79	1	R24	RES 10 kOhms 5% 1/10W 0603	YAGEO	RC0603FR-0710KL	0603
80	1	R25	RES 10 KOhm 5% 1/10W 0603	YAGEO	RC0603FR-0710KL	0603
81	1	R26	RES 100 KOhm 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT100K	0603
82	1	R36	RES 4.7 KOhm 5% 1/16W 0402	YAGEO	RC0402JR-074K7L	0402
83	1	R37	RES 1 KOhm 5% 1/4W 1206	YAGEO	RC1206JR-071KL	1206
84	1	R39	RES SMD 0 Ohm 1/10W 0603	YAGEO	AC0603FR-070RL	0603
85	1	R49	RES 100 KOhm 1% 1/8W 0402	YAGEO	AC0402FR-7W100KL	0402
86	1	R50	RES SMD 49.9 KOhm 1% 1/10W 0402	Panasonic Electronic Components	ERJ-2RKF4992X	0402
87	1	R51	RES SMD 49.9 KOhm 1% 1/10W 0402	Panasonic Electronic Components	ERJ-2RKF4992X	0402
88	1	R52	RES SMD 49.9 KOhm 1% 1/10W 0402	Panasonic Electronic Components	ERJ-2RKF4992X	0402
89	1	R53	RES SMD 49.9 KOhm 1% 1/10W 0402	Panasonic Electronic Components	ERJ-2RKF4992X	0402
90	1	R54	RES SMD 1 Ohm 1% 1/8W 0805	Vishay Dale	CRCW08051R00FKEA	0805
91	1	R138	RES DNP	DNP	DNP	0805
92	1	R139	RES DNP	DNP	DNP	0805
93	1	R140	RES DNP	DNP	DNP	0805
94	1	R141	RES DNP	DNP	DNP	0805
95	1	R148	RES DNP	DNP	DNP	0402
96	1	R154	RES SMD 680 Ohm 5% 1/4W 0603	Rohm Semiconductor	CR0402-FX-2001GLF	0603
97	1	R155	RES 0.05 Ohm 5% 1/5W 0603	Panasonic Electronic Components	ERJ-L03KJ50MV	0603
98	1	R160	RES SMD 0 Ohm 1/10W 0603	YAGEO	AC0603FR-070RL	0603
99	1	R166	RES DNP	DNP	DNP	0402
100	1	U1	QUASI RESONANT FLYBACK CONTROLLER	onsemi	NCP1342AMDBDD1R2G	SOIC−9 NB

Bill of Materials - Mother Board						
Item	Quantity	PCB Reference	Part Description	Manufacturer	Manufacturer PN	Package
101	1	U3	Optoisolator 3.75KV	onsemi	FODM8801AV	4-soic
102	1	U4	FUSE BRD MNT 3.15A 250VAC RADIAL	Littelfuse Inc.	39213150000	Through Hole
103	1	U5	FLYBACK TRANSFORMER	Wurth Eectronics	750319815 or equivalent	RM8
104	1	U7	MOSFET N-CH 120V 18.5A/114A 8QFN	onsemi	FDMS4D0N12C	8-PQFN
105	1	U8	SR Controller	onsemi	NCP43080DMNTWG	DFN-8
106	1	U47	DIODE ZENER 10V 300MW SOD323	onsemi	MM3Z10VT1G	SOD-323
107	1	U50	BRIDGE RECT 1PHASE 800V 4A Z4-D	Comchip Technology or equivalent	Z4DGP408L-HF	Z4-D
108	1	U51	BRIDGE RECT 1PHASE 800V 4A Z4-D	Comchip Technology or equivalent	Z4DGP408L-HF	Z4-D
109	1	U52	360mΩ, 650V GaN HEMT	Tagore Technology	TP44400SG	QFN 5x7

Daughter Board (PD controller) BOM:

Bill of Materials - PD Card						
Item	Quantity	PCB Reference	Part Descriptions	Manufacturer	Manufacturer PN	Package
1	1	C25	CAP CER 470PF 50V X7R 0402	Wurth Eectronics	885012205059	0402
2	1	C211	CAP CER 470PF 50V X7R 0402	Wurth Eectronics	885012205059	0402
3	1	C33	CAP CER 1000PF 50V X7R 0603	Wurth Eectronics	885012206083	0603
4	1	C34	CAP CER 1UF 25V X7R 0603	Samsung Electronics	CL10B105KA8NNNC	0603
5	1	C150	CAP CER 1UF 25V X7R 0603	Samsung Electronics	CL10B105KA8NNNC	0603
6	1	C151	CAP CER 1UF 25V X7R 0603	Samsung Electronics	CL10B105KA8NNNC	0603
7	1	C145	CAP CER 4700PF 50V X7R 0603	Wurth Eectronics	885012206087	0603
8	1	C152	CAP CER 4700PF 50V X7R 0603	Wurth Eectronics	885012206087	0603
9	1	C147	CAP CER 1000PF 50V X7R 0402	Wurth Eectronics	885012205061	0402
10	1	C148	CAP CER 390PF 50V X7R 0402	Wurth Eectronics	885012205059	0402
11	1	C149	CAP CER 390PF 50V X7R 0402	Wurth Eectronics	885012205059	0402
12	1	D35	TVS DIODE 48VC 2X2DFN	On Semi	ESD7241N2T5G	X2DFN-2
13	1	J62	CONN RCP USB3.1 TYPEC 24P SMD RA	Molex	1054500101	USB C connector
14	1	R27	RES 100 OHM 1% 1/16W 0402	Stackpole Electronics Inc	RMCF0402FT100R	0402
15	1	R31	RES 10 OHM 1% 1/16W 0402	Stackpole Electronics Inc	RMCF0402FT10R0	0402
16	1	R33	RES SMD 1K OHM 5% 1/10W 0402	Panasonic Electronic	ERJ-2GEJ102X	0402
17	1	R42	RES SMD 1K OHM 5% 1/10W 0402	Panasonic Electronic	ERJ-2GEJ102X	0402
18	1	R34	RES 0.004 OHM 1% 1/4W 1206	Vishay Dale	WSL12064L000FEA	1206
19	1	R35	RES 39.2 OHM 1% 1/2W 1210	Stackpole Electronics Inc	RMCF1210FT39R2	1210
20	1	R38	RES SMD 120K OHM 1% 1/10W 0402	Panasonic Electronic	ERJ-2RKF1203X	0402
21	1	R39	RES SMD 13K OHM 1% 1/10W 0402	Panasonic Electronic	ERJ-2RKF1302X	0402
22	1	R40	RES SMD 10K OHM 1% 1/10W 0402	Yageo	RC0603FR-7W10KL	0402
23	1	R41	RES SMD 220K OHM 1% 1/10W 0402	Panasonic Electronic	ERJ-2RKF2203X	0402
24	1	U23	MOSFET N-CH 30V 17.5A/19.5A 8MLP	On Semi	FDMC7678	Power-33-8
25	1	U25	USB POWER DELIVERY 3.0 ADAPTIVE	On Semi	FUSB3307D6MX	SOIC-14

8 REVISION HISTORY

Document version	Date of release	Description of changes
Rev 1.0	27-Dec-22	First release