TP44100SG-TPPFC240-EVB

240 W Totem-Pole PFC Evaluation Board Using Tagore Technology's Superior GaN HEMT (TP44100SG)

User Manual

Rev-2.0

2023-August-16

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About this document

Objective and Purpose:

This application note describes Tagore Technology's 240 W Totem-Pole PFC (TP-PFC) Converter Evaluation Board (TP44100SG-TPPFC240-EVB) using its 90 mΩ superior GaN HEMT TP44100SG. The user will be able to perform a 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.) is 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 90 mΩ Superior GaN HEMT TP44100SG.

Revision History

Document version	Date of release	Description of changes
Rev 1.0	21-Nov-2022	First release.
Rev 2.0	16-Aug-2023	Design Rev-2, all sections rearranged and revised.

Contents

1 Introduction

In most of the power supplies and battery chargers connected to grid, ac-dc power conversion serves as the first-stage power conversion block. Above 75 W output power, regulations require incorporation of a Power Factor Correction (PFC) stage in the ac-dc converter.

The **TP44100SG-TPPFC240-EVB** is a highly efficient single phase Totem Pole PFC (TP-PFC) solution, which is built using the advantages of Tagore Technology's Superior GaN HEMT **TP44100SG**. The EVB can operate over the universal input ac voltage range (90 V to 265 V) providing output power up to 240 W with efficiency more than 98%. Such high efficiency cannot be achieved using a standard Boost PFC due to high power loss in the Diode Bridge Rectifier (DBR) at its input. The Totem Pole PFC topology replaces the inefficient diodes bridge with semiconductor switches. Tagore Technology's "Enhancement Mode High Electron Mobility GaN Transistors (E-HEMTs) with ESD protection" parts have very low output charge (Q_{oss}), and reverse recovery charge (Q_{rr}) is completely absent. These advantages of Tagore Technology's Superior GaN part **TP44100SG** were leveraged to design this TP-PFC solution with low switching loss which further enhanced efficiency.

Figure 1-1: Photograph of TP44100SG-TPPFC240-EVB.

Lower loss allows the GaN HEMTs to operate continuously without any external heatsink reducing volume and weight of the EVB. The TP44100SG parts are Surface Mount Devices (SMDs) which come in small QFN 5 X 7 package. This enables the layout design to be compact and improves EMI due to lower voltage oscillations during switching. Utilizing these advantages, the TP-PFC solution presented here has a small form factor and consequently has a high energy density. Additional thermal management like fan and heatsink are not required and usage of SMD components makes the assembly process faster and cheaper. Thus, this TP-PFC solution using Tagore Technology's Superior GaN is an ideal candidate for a simple, compact, and cost-effective PFC application.

1.1 Working Principle

The TP-PFC has four switching devices: Two High Frequency (HF) GaN HEMT and two Low Frequency (LF) Super-Junction (SJ) MOSFETs as shown in Figure 1-2. The LF devices are turned ON and OFF alternately in each line cycle. This divides the TP-PFC into two different functional boost converters with synchronous rectification. The HF leg GaN HEMTs change their role between boost switch and boost diode every half line cycle. During the positive half cycle, SRL is ON and SRH is OFF. Here, S2 acts as the boost switch, driven with duty cycle D, and S1 acts as the boost diode, driven with complementary

PWM signal of duty (1-D). Similarly, during the negative half line cycle, SRH remains ON and SRL OFF. S2 acts as the boost diode and S1 as the boost switch.

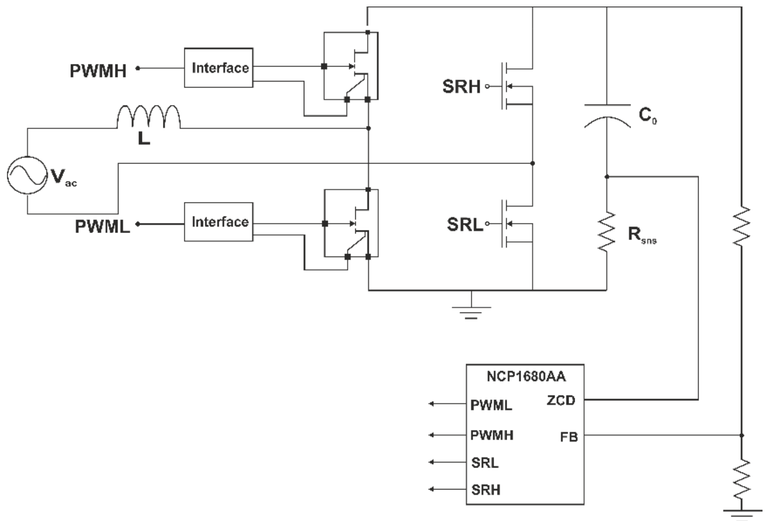


Figure 1-2: Functional block diagram of EVB.

The NCP1680 is a Critical Conduction Mode (CrM) PFC controller IC dedicated for TP-PFC topology. In a switching cycle when the boost switch turns on inductor current rises in magnitude. After the boost switch turns off, this inductor current gradually returns to zero as the output capacitor gets charged. The controller needs to detect the exact instant when the inductor current just falls to zero so that it can initiate the next switching cycle. This is achieved through negative dc bus current sensing (ZCD sense) as shown in Figure 1-2. The TP-PFC also operates at DCM at light loads, and during some part of the line cycle to prevent the switching frequency going very high. During this time, the boost GaN switches are turned on at QR valleys to reduce the turn on switching losses and to improve the EMI performance. The switch node valleys are being sensed using an auxiliary winding, coupled to the boost inductor, and the information is fed to the controller IC as shown in Figure 1-2. Three resistor potential divider networks are used: the first two for sensing the line voltage, and the rest for output dc bus voltage sense.

The controller IC does not have integrated gate drivers to drive the semiconductor switches. So, external half-bridge level-shifted gate driver ICs (NCP 51530) are required to drive both the HF and LF legs of the TP-PFC converter. These gate drivers take PWM signals from the controller IC as inputs and generate gate drive output pulses of 12 V as high level and 0 V as low level. Since the GaN HEMTs need +6V/0V gate drive signals, interface circuit/level-down-shifter circuit has been used between the gate terminal of each GaN HEMT and its respective gate driver output. The interface circuit is illustrated in Figure 1-3.

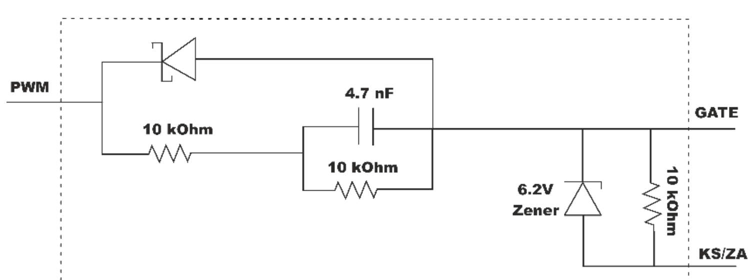
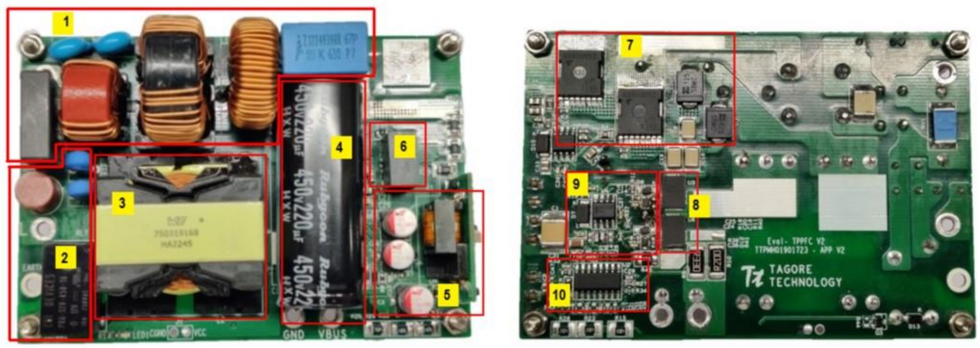


Figure 1-3: Gate Interface Circuit.

The controller does not have self-startup functionality. It needs external bias supply for startup and run. The entire control circuit, including gate drivers, has been designed to work with 12 V_{dc} supply. An auxiliary power supply daughter board is used. It takes power from the output dc bus (~400 V) and provides 12 V_{dc} to the controller circuit. During startup, when the TP-PFC is yet to become functional, the output dc bus capacitor gets peak charged to the peak of the line voltage through the body diodes of the LF MOSFETs and the bypass diodes and provides the initial bias power. The bias power supply has been designed to operate from very low voltage (~50 V_{dc}) to maximum possible dc bus voltage (~400 V).

2 Physical Details and Specifications Of EVB

Photographs of both the top and the bottom sides of the TP-PFC EVB are shown in Figure 2-1 with key components identified.



Top Side

Bottom Side

1	Input EMI Filter
2	Inrush Control
3	PFC Inductor
4	Output Capacitor
5	Controller Bias
6	High Side Driver Bias
7	Si MOSFETs & Drive Ckt.
8	GaN FETs in High Freq
9	GaN Driver circuits
10	Controller

Figure 2-1: Top (Left) and Bottom (Right) views of the EVB with key circuit blocks identified.

2.1 Dimension Measurements

Table 2-1 : Mechanical Dimensions

Mechanical Dimensions	Value	Unit
Length of EVB PCB	98.02	mm
Width of EVB PCB	67.21	mm
Thickness of EVB PCB	1.6	mm
Height of tallest component on Top Side	28	mm
Height of tallest component on Bottom Side	2.8	mm
Gross Volume of EVB	213.45	cc

2.2 Technical Data

Table 2-2 : Key Technical Specifications

PARAMETER	TEST CONDITIONS	MIN	NOM	MAX	UNIT
Input RMS Voltage (V_{in})		90		265	V_{ac}
Line Frequency		47		63	Hz
Output voltage		395	400	405	V_{dc}
Output current			0.6		A
Output voltage ripple	Peak -to- Peak			10	V
Output power			240		W
Efficiency	V_{in} = 230V, full load.		98.3		%
Switching frequency		35		120	kHz

3 Operating Procedure

3.1 List Of Instruments and Hardware Items Required

For testing the Eval Board, following list of instruments and hardware items are required:

- TP44100SG-TPPFC240-EVB
- Ac Power Source: Output voltage within 90 V_{ac} to 265 V_{ac}; capable of delivering 250 W power.
- Load: Electronic Load or Resistive Load (400 V_{dc} min., 240 W)
- Observation Instruments:
  - Digital Power Meter – GWInstek GPM-8213 or equivalent
  - Digital Multimeters for measuring voltages and currents (300 V_{ac} min., 5 A min.)
  - Digital Storage Oscilloscope (DSO) (Preferably with 4 Channels, BW ≥ 300 MHz)
  - High Voltage Differential Probes (min. 500 V) compatible with the DSO
  - Current Clamp Probes (min. 10 A) compatible with the DSO
- Wires and cables for making electrical connections.

3.2 Operating Procedure Steps

- Ensure that the dc bus capacitors are discharged, the output voltage of EVB is zero, and the ac power source is turned off.
- Connect the input power terminals of the EVB to the output terminals of the ac power source. (Optional: Connect a power meter in between the EVB input and ac power source output).
- Set electronic load value to 0A in constant current mode and ensure loading is disabled. Connect the output terminals of the EVB to the electronic load in correct polarity.
- Connect voltage, current probes from DSO to the desired observation points.
- Set the output of the ac power source to 0 V_{ac} and then switch it on. Gradually increase the ac output to 90 V_{ac}. Observe that the EVB output voltage will rise to ~400 V_{dc} and maintain the same value indicating that the EVB startup is complete.
- Enable the electronic load and then gradually increase the loading to the desired value not exceeding the maximum output power rating of the EVB while doing these experiments.
- After completing experiments, turn off the ac input power source. Wait for some more time for the output dc bus to get discharged before touching the board.

4 Experimental Results

4.1 Efficiency

Efficiency measurement test is done by measuring the input power using a digital power meter, while the output voltage and currents were measured by the electronic load. Measured efficiency of the EVB at various loads for different input voltages is shown in Figure 4-1.

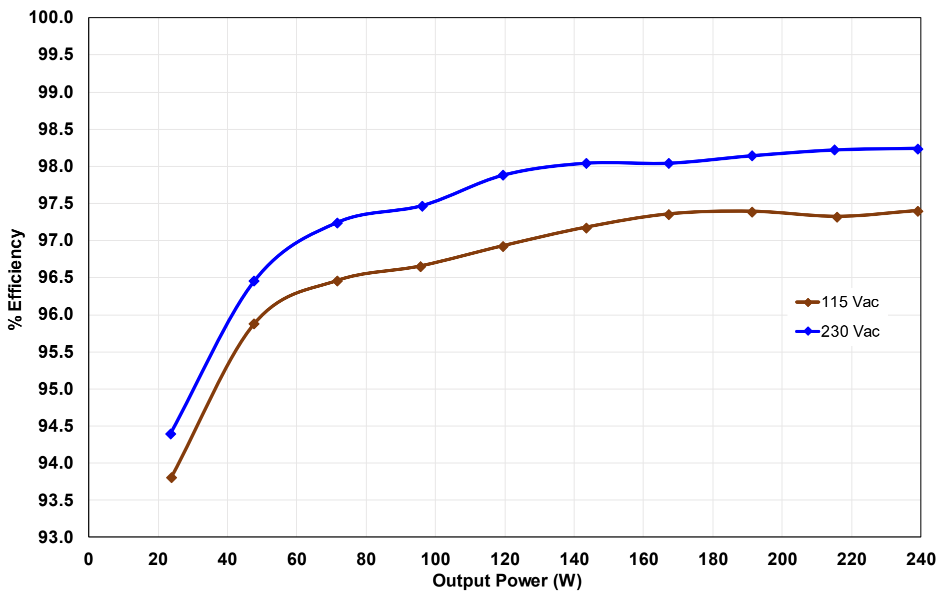


Figure 4-1: EVB Efficiency measured at five different input voltages: 115 and 230 V_{ac}.

4.2 Power Factor

Power factor curves vs output power at different input voltages are shown in Figure 4-2.

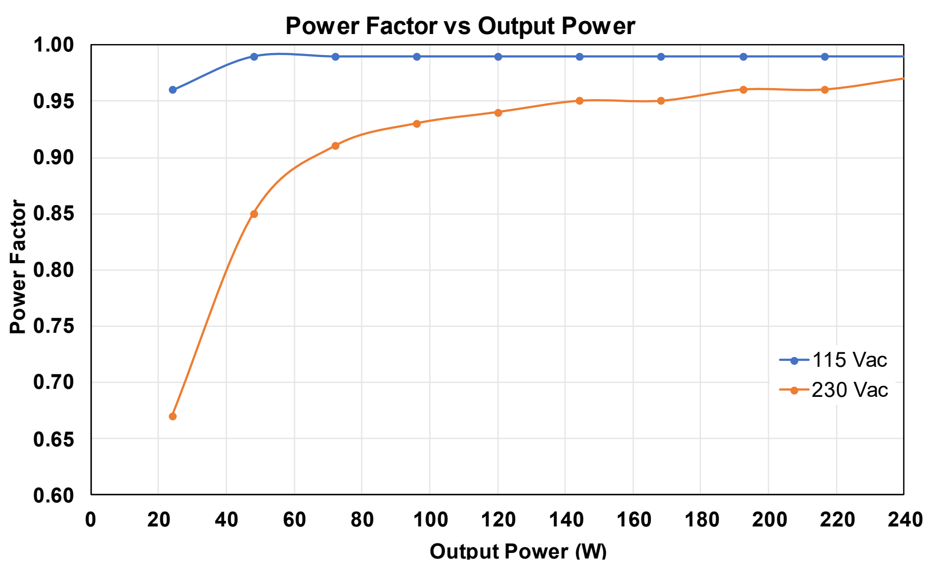


Figure 4-2: Power Factor vs Output Power at 115 V_{ac} and 230 V_{ac}.

4.3 Steady-State Input Waveforms

Typical steady state input voltage and current waveforms of the EVB for different cases:

- Input Voltage: 115 V_{ac} and Output Power: 240 W is shown in Figure 4-3.
- Input Voltage: 230 V_{ac} and Output Power: 240 W is shown in Figure 4-4.
- Input Voltage: 115 V_{ac} and Output Power: 120 W is shown in Figure 4-5.
- Input Voltage: 230 V_{ac} and Output Power: 120 W is shown in Figure 4-6.

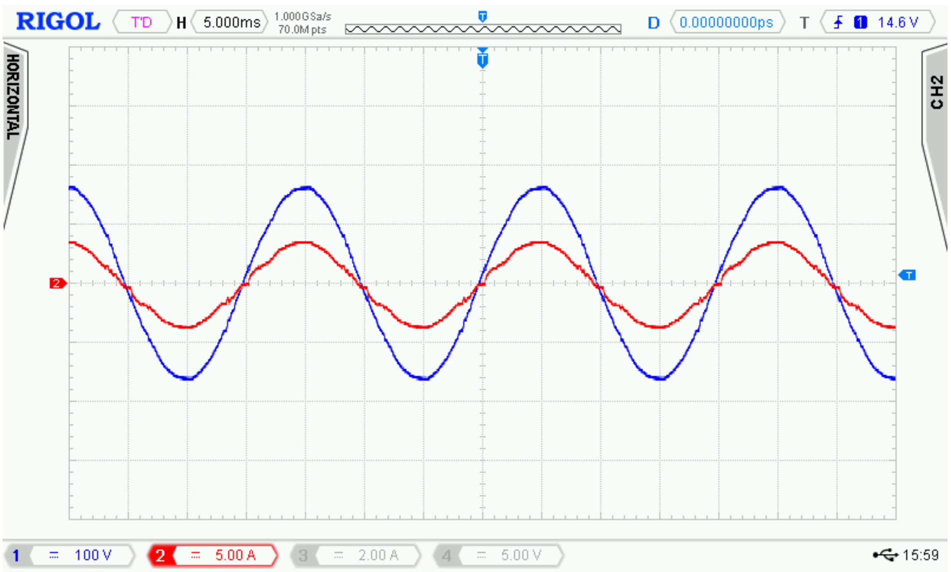


Figure 4-3: Input voltage and current waveforms at 240 W load when supply voltage is 115 V_{ac}. Channel 1(Blue): Input voltage (100 V/div.); Channel 2(Red): Input current (5 A/div.); time: 5 ms/div .

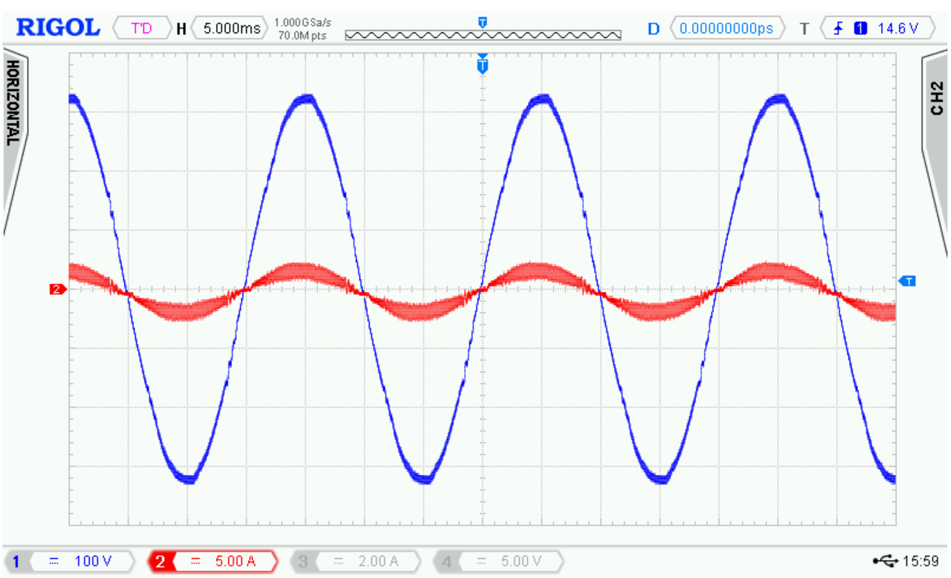


Figure 4-4: Input voltage and current waveforms at 240 W load when supply voltage is 230 V_{ac}. Channel 1(Blue): Input voltage (100 V/div.); Channel 2(Red): Input current (5 A/div.); time: 5 ms/div.

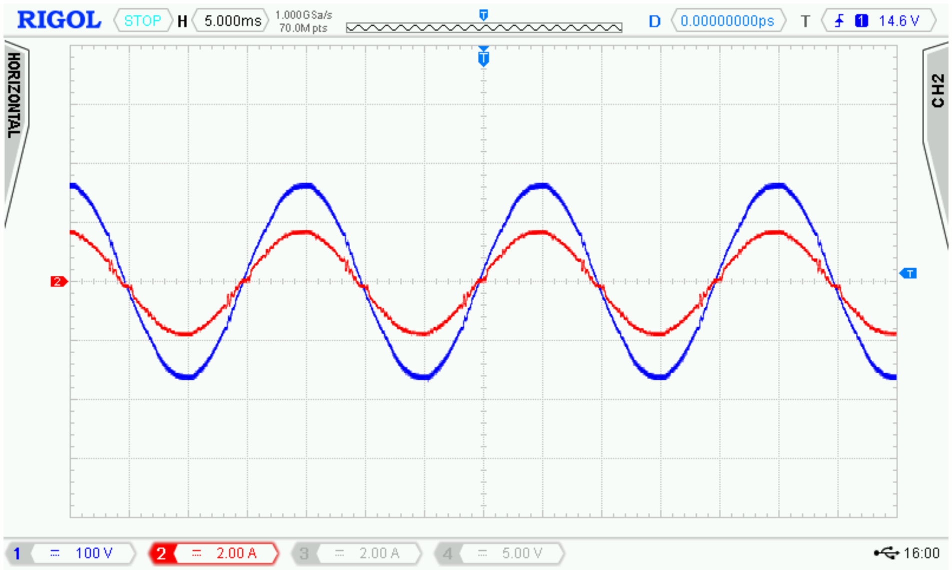


Figure 4-5: Input voltage and current waveforms at 120 W load when supply voltage is 115 V_{ac}. Channel 1(Blue): Input voltage (100 V/div.); Channel 2(Red): Input current (1 A/div.); time: 5 ms/div.

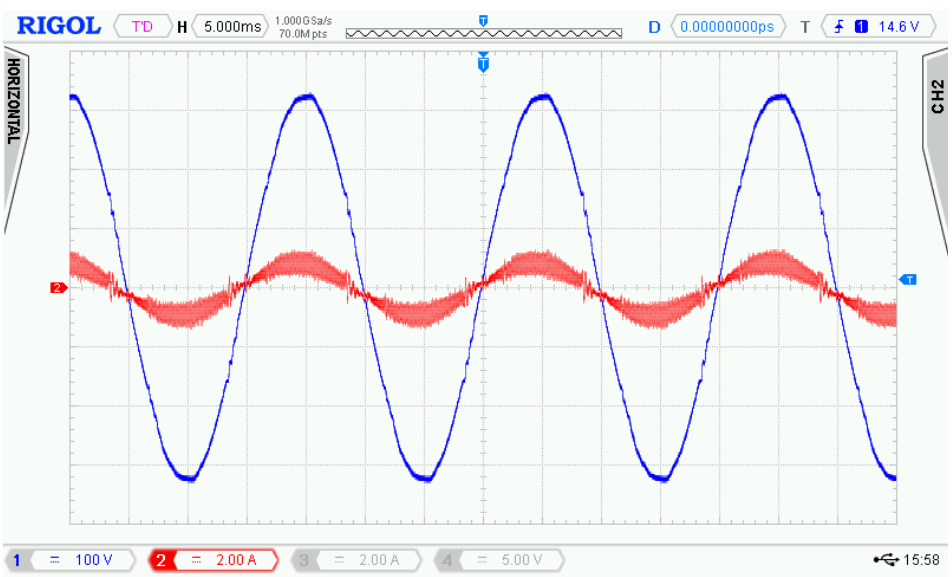


Figure 4-6: Input voltage and current waveforms at 120 W load when supply voltage is 230 V_{ac}. Channel 1(Blue): Input voltage (100 V/div.); Channel 2(Red): Input current (1 A/div.); time: 5 ms/div.

THD of the input current at two input voltages 230 V_{ac} and 115 V_{ac} for different loads are given in the table below:

Output Power (W)	THD % at 230 V_{ac}	THD % at 115 V_{ac}
240	3.7	5.3
168	4.4	2.7
120	5.0	3.0

4.4 Start-up

The EVB is designed to limit the inrush current during start-up and the output voltage gradually builds up without any overshoot. The no load start-up waveforms of the EVB at 115 V_{ac} and 230 V_{ac} which are shown in Figure 4-7 and Figure 4-8 respectively indicate that the start-up procedure is completed in less than 0.5 s.

Figure 4-7: No-load start-up at 115 V_{ac} input. Channel 1(Blue): Input ac voltage (200 V/div); Channel 2(Red): Input ac current (5 A/div); Channel 3(Green): TP-PFC high frequency leg switch node voltage (200 V/div); Channel 4(Orange): Output voltage (200 V/div); time: 50 ms/div.

Figure 4-8: No-load start-up at 230 V_{ac} input. Channel 1(Blue): Input ac voltage (500 V/div); Channel 2(Red): Input ac current (5 A/div); Channel 3(Green): TP-PFC high frequency leg switch node voltage (200 V/div); Channel 4(Orange): Output voltage (200 V/div); time: 50 ms/div.

4.5 Load Step Change Transient Response

The TP-PFC EVB has very fast Transient response. Output voltage transients due to 0 - 100 % and vice-versa step changes in load as shown in Figure 4-9 and Figure 4-10 respectively, at 115 V_{ac} and 230 V_{ac} input voltages. Voltage undershoots and overshoots are less than 0.8% of the nominal output voltage.

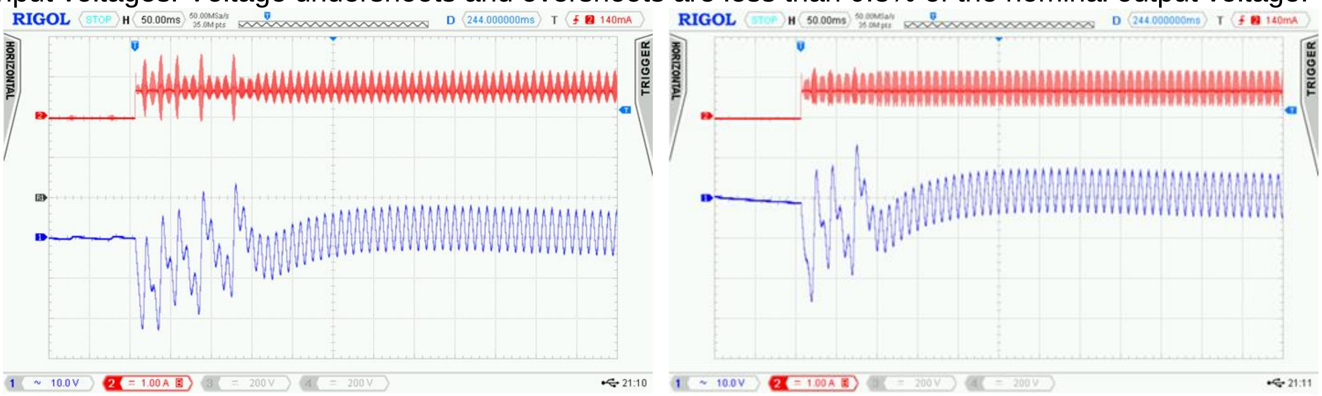


Figure 4-9: PFC output voltage transient due to 0-100% Load step change at (Left) 115 V_{ac} and (Right) 230 V_{ac}. Channel 1 (Blue): Output Voltage (10 V/div); Channel 2(Red): Output Load current (1 A/div); time: 50 ms/div.

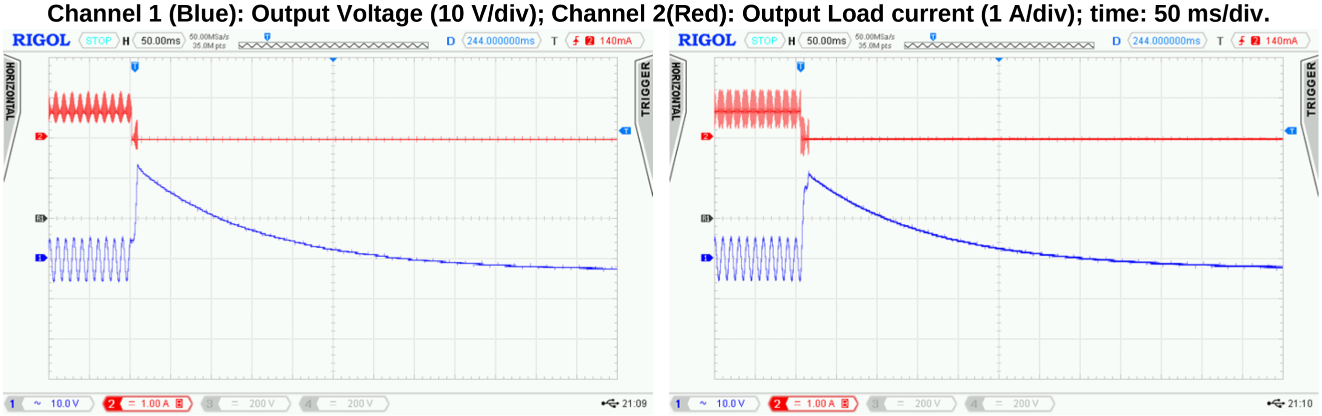


Figure 4-10: PFC output voltage transient due to 100-0% Load step change at (Left) 115 V_{ac} and (Right) 230 V_{ac}. Channel 1 (Blue): Output Voltage (10 V/div); Channel 2(Red): Output Load current (1 A/div); time: 50 ms/div.

4.6 Output Voltage Ripple Switching Waveforms

Output voltage ripple waveform at full load at 115 V and 230 V is shown in Figure 4-11. Peak to peak ripple is limited to 10 V.

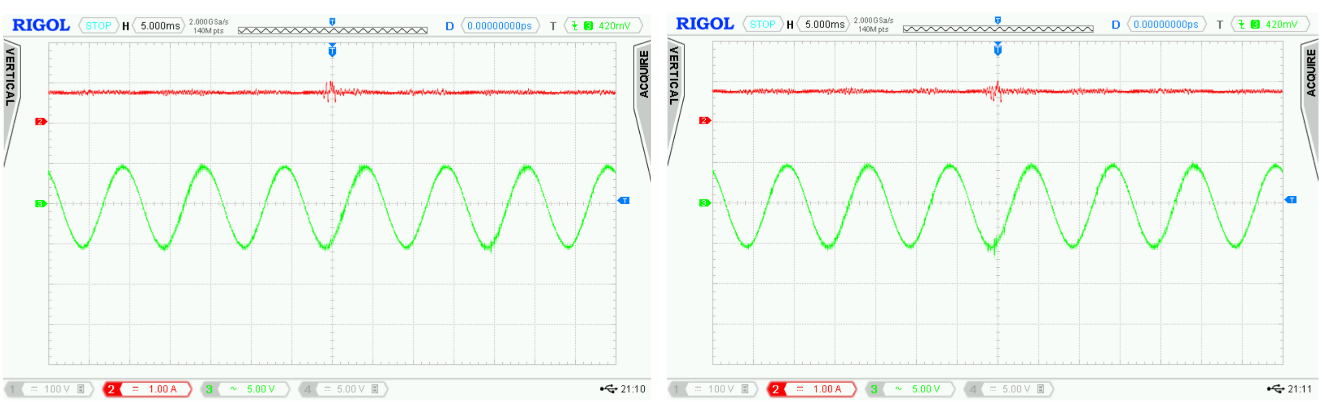


Figure 4-11: Output voltage ripple waveforms on full load at (Left) 115 V_{ac} and (Right) 230 V_{ac}. Channel 2(Red): Output Load current (2 A/div.); Channel 3(Green): Output voltage ripple (5 V/div.).

4.7 Switching Waveforms

The high frequency switch node voltage and the corresponding Gate-Source voltage signal of the Low side GaN HEMT of the high frequency leg of the TP-PFC are shown in Figure 4-12.

Figure 4-12: Channel 1(Blue): High Frequency switch node voltage (100 V/div.); Channel 2(Red): Gate-Source voltage of the Low side GaN FET (10 V/div.); Channel 3(Green): Input current (2 A/div.); (Above) Waveforms captured over few line cycles, (Below) zoomed to 5 µs/div.

4.8 Thermal Performance

The thermal performance of the GaN HEMTs at 115 V_{ac} input and 240W output power is captured and shown in Figure 4-13. Ambient temperature was 25℃.

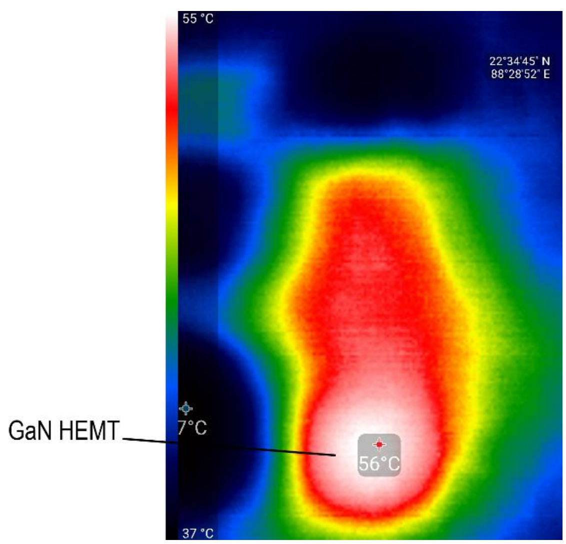


Figure 4-13: Temperature measurement of GaN HEMTs at full load and 115V_{ac} input.

5 PCB Layout

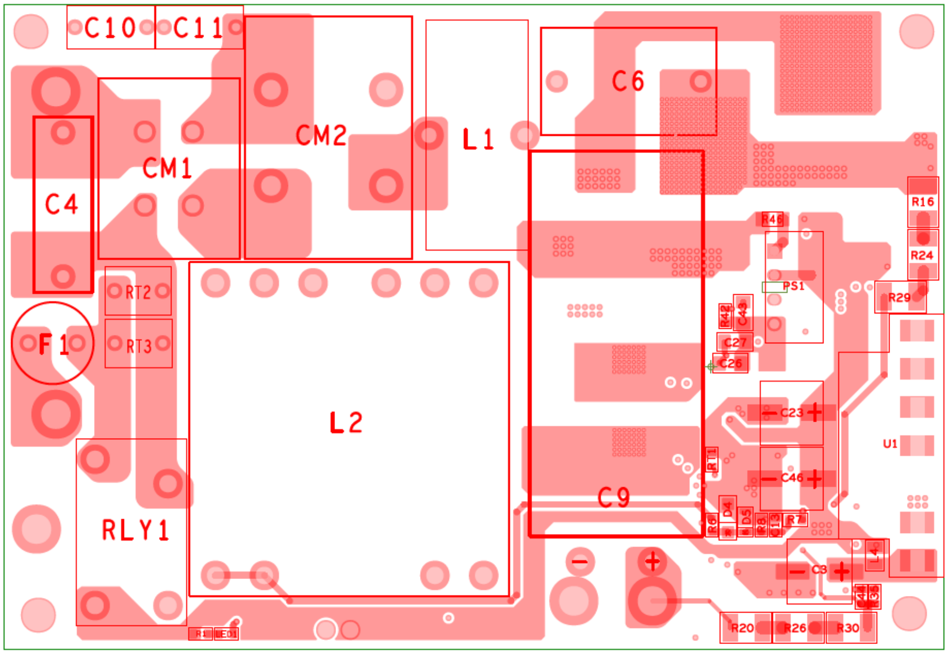


Figure 5-1: Top layer.

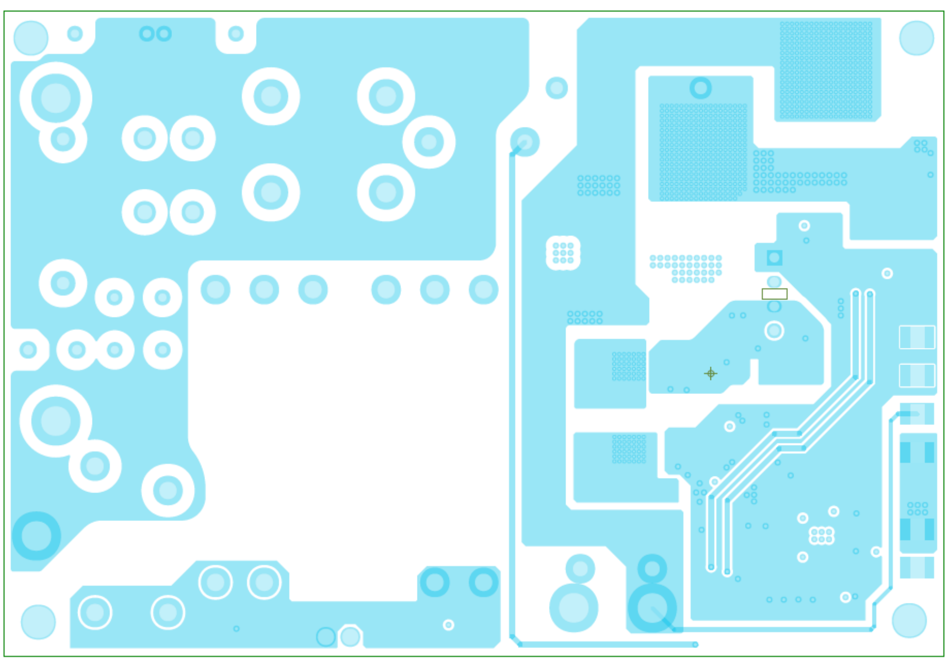


Figure 5-2: Mid layer 1.

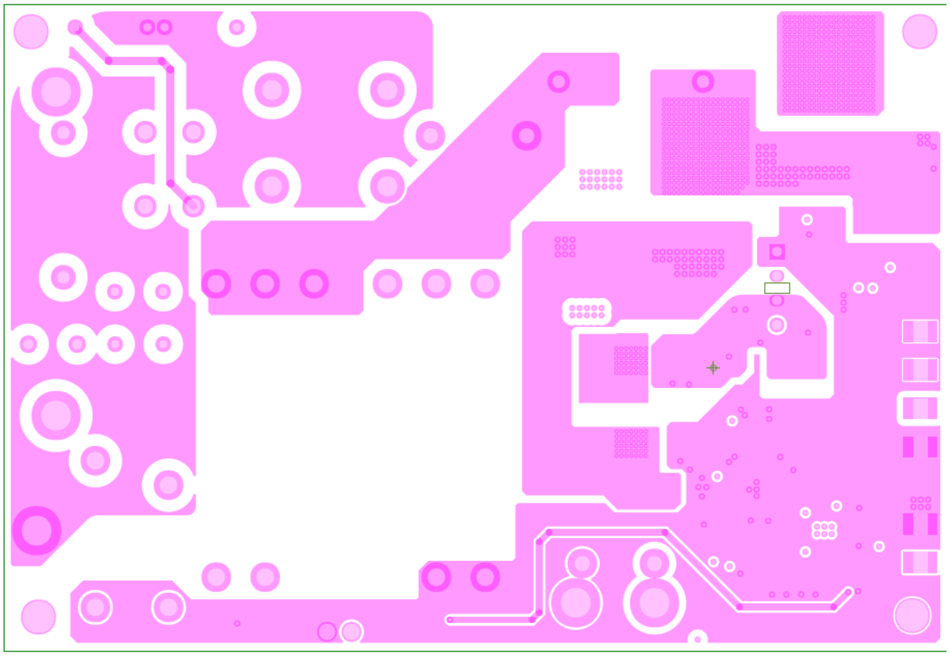


Figure 5-3: Mid layer 2.

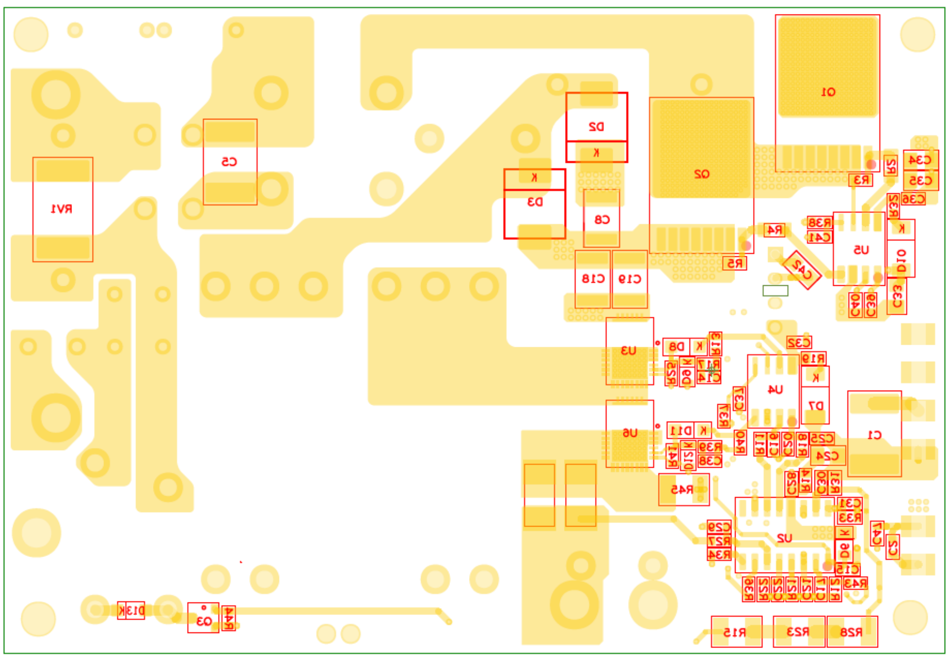


Figure 5-4: Bottom layer.

6 Bill Of Materials

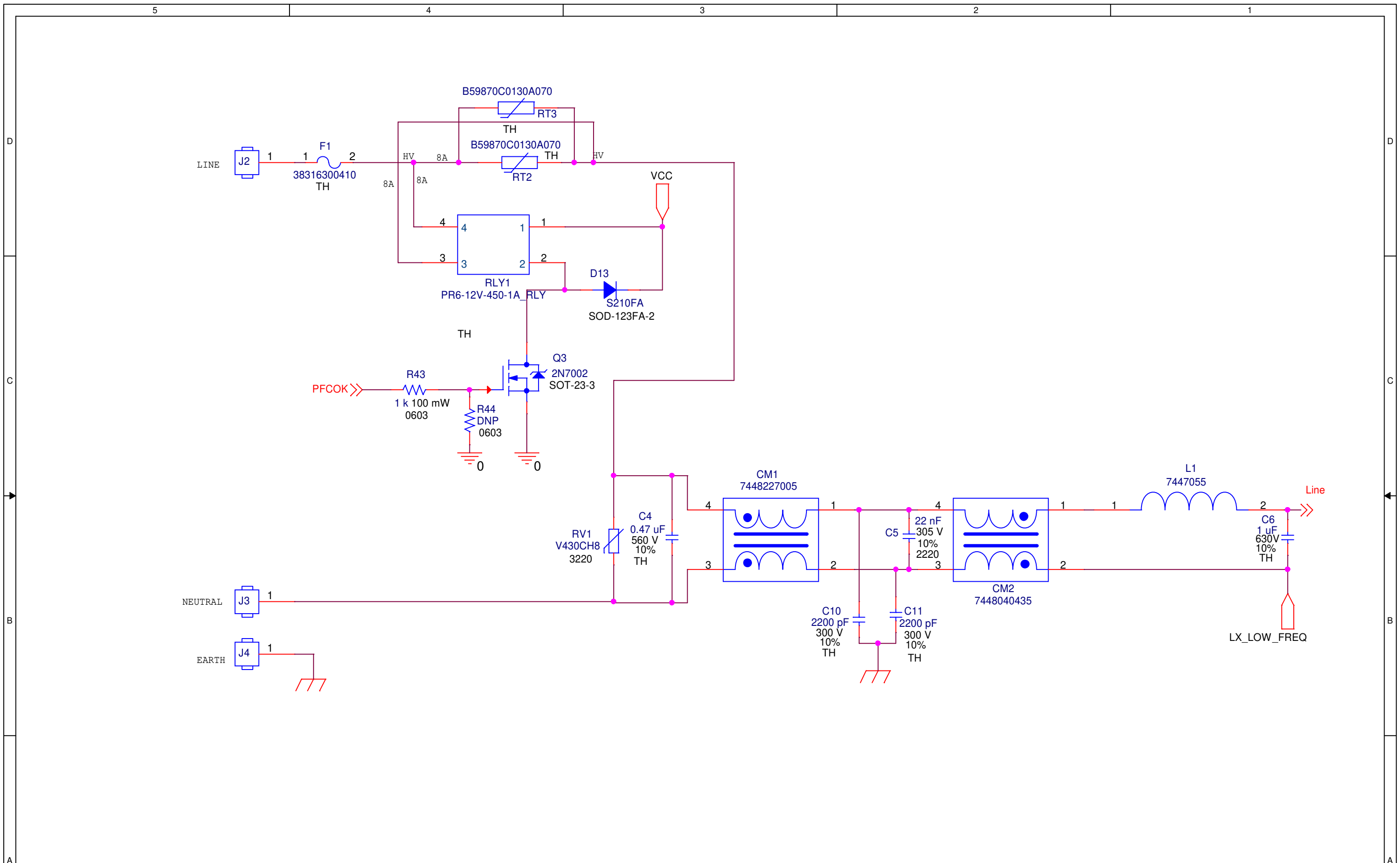
Table 6-1: Bill of Materials (BOM)

240 W TP-PFC EVB BOM								
Sl #	Qty	Reference	Description	Value	Rating	Package	Part Number	Manufacturer
1	1	CM1	Common Mode Choke	0.45 mH	6.5 A		7448227005	Wurth Elektronik
2	1	CM2	Common Mode Choke	35 mH	3.5 A		7448040435	Wurth Elektronik
3	1	C1	MLCC, X7R, 10%	1 µF	630 V	2220	885342214001	Wurth Elektronik
4	3	C2, C41, C47	MLCC, X7R, 10%	1 µF	50 V	0603	Standard Part	
5	1	C3	Electrolytic Capacitor	220 µF	16 V		Standard Part	
6	1	C4	Film Capacitor, X2, 20%	0.47 µF	560 V	2220	R46KI347045P2M	KEMET
7	1	C5	MLCC, X7R, 10%	22 nF	50 V	2220	2220YA300223KJTS3X	Knowless Syfer
8	1	C6	Film Capacitor, 10%	1 µF	630 V		B32672P6105K000	EPCOS/ TDK
9	2	C7, C12	MLCC, X7R, 10%	1000 pF	630 V	1206	CC1206KKX7RZBB102	Yageo
10	3	C8, C18, C19	MLCC, X7R, 10%	0.1 µF	1 kV	1812	C1812C104KDRACTU	KEMET
11	1	C9	Electrolytic Capacitor	220 µF	450 V		450HXW220MEFR18X45	Rubycon
12	2	C10, C11	Ceramic Cap., 20%	2200 pF	300 V		DE6E3KJ222MA3B	Murata Electronics
13	1	C13	MLCC, X7R, 10%	33 pF	50 V	0603	Standard Part	
14	2	C14, C38	MLCC, X7R, 10%	4.7 nF	50 V	0603	Standard Part	
15	1	C15	MLCC, X7R, 20%	10 nF	50 V	0603	Standard Part	
16	2	C16, C20	MLCC, X7R, 20%	320 pF	50 V	0603	Standard Part	
17	2	C39, C40	MLCC, X7R, 10%	100 pF	50 V	0603	Standard Part	
18	1	C17		DNP		0603		
19	2	C21, C44	MLCC, C0G, 5%	2.2 nF	50 V	0603	Standard Part	
20	1	C22	MLCC, X7R, 10%	47 pF	50 V	0603	Standard Part	
21	1	C23	Al. Electrolytic Cap., 20%	100 µF	35 V		865080545012	Wurth Elektronik
22	1	C24	MLCC, X7R, 10%	2.2 µF	50 V	0805	Standard Part	
23	5	C25, C28, C32, C36, C37	MLCC, X7R, 20%	0.1 µF	50 V	0603	Standard Part	
24	5	C26, C27, C33, C34, C35	MLCC, X7R, 10%	22 µF	50 V	0805	Standard Part	
25	1	C29	MLCC, X7R, 10%	220 pF	50 V	0603	Standard Part	
26	2	C30, C31	MLCC, X7R, 10%	1 nF	50 V	0603	Standard Part	
27	2	C42, C43	MLCC, X7R, 10%	4.7 µF	50 V	0805	Standard Part	
28	1	C46	Al. Electrolytic Cap., 20%	47 µF	35 V		Standard Part	
29	1	D1	LED Green				APT1608ZGC-AMT	Kingbright
30	2	D2, D3	Rectifier	1 kV		SMC	S8MC-13	Diode Incorporated
31	3	D4, D8, D11	Schottky Diode	30 V	400 mW	SOD-123	BAT54T1G	Onsemi
32	1	D5	Zener Diode	5.1 V	200 mW	SOD-323	BZT52-B5V1S	Panjit
33	1	D6	Zener Diode	15 V	400 mW	SOD-323F	D3Z15BF-7	Diode Incorporated
34	2	D7, D10	Diode	600 V	1 A	DO-214	ES1JAF	Onsemi
35	2	D9, D12	Zener Diode	6.2 V	300 mW	SOD-323	SZMM3Z6V2ST1G	Onsemi
36	1	D13	Schottky Diode	100 V	2 A	SOD-123FA	S210FA	Onsemi
37	1	F1	Fuse		6.3 A		38316300410	Littlefuse
38	1	K1	Relay	12 V	10 A		PR6-12V-450-1A	CUI Devices
39	2	L1, L2	Inductor	150 µH	5.4 A		7447055	Wurth Elektronik
40	1	L4	Inductor	4.7 µH	0.6 A		74479775247	Wurth Elektronik
41	1	PS1	Isolated dc-dc Converter		12 V	SIP-4	PDS1-S12-S12-S	CUI Inc.
42	2	Q1, Q2	N channel MOSFET	70 mΩ	650 V	2-10AF1A	TK090U65Z	Toshiba
43	1	Q3	N channel MOSFET			SOT-23	2N7002	Onsemi
44	1	RT1	NTC	100 kΩ	100 mW	0603	NCU18WF104D60RB	
45	2	RT2, RT3	PTC	50 Ω			B59870C0130A070	EPCOS/ TDK
46	1	RV1	Varistor	275 V	250 A	3220	V430CH8	Littlefuse

240 W TP-PFC EVB BOM								
Sl #	Qty	Reference	Description	Value	Rating	Package	Part Number	Manufacturer
47	7	R1, R3, R5, R17, R25, R39, R41	Resistor, 1%	10 kΩ	100 mW	0603	Standard Part	
48	2	R2, R4	Resistor, 1%	20 Ω	100 mW	0805	Standard Part	
49	1	R6	Resistor, 1%	4.7 kΩ	100 mW	0603	Standard Part	
50	2	R7, R19	Resistor, 1%	0 Ω	100 mW	0603	Standard Part	
51	1	R8	Resistor, 1%	4.99 kΩ	100 mW	0603	Standard Part	
52	1	R9	Current sense Resistor	330 mΩ	2 W	2512	MFLA2512R3300FC	Eaton
53	1	R10	Current sense Resistor	200 mΩ	2 W	2512	MFHA2512R2000FE	Eaton
54	2	R11, R18	Resistor, 1%	100 Ω	100 mW	0603	Standard Part	
55	1	R12	Resistor, 1%	200 kΩ	100 mW	0603	Standard Part	
56	2	R13, R40	Resistor, 1%	49.9 Ω	100 mW	0603	Standard Part	
57	3	R14, R37, R38	Resistor, 1%	2.2 Ω	100 mW	0603	Standard Part	
58	6	R15, R16, R23, R24, R28, R29	Resistor, 1%	3.3 MΩ	250 mW	1206	Standard Part	
59	3	R20, R26, R30	Resistor, 1%	7.5 MΩ	250 mW	1206	Standard Part	
60	1	R21	Resistor, 1%	DNP	100 mW	0603	Standard Part	
61	1	R22	Resistor, 1%	10 Ω	100 mW	0603	Standard Part	
62	2	R27, R43	Resistor, 1%	1 kΩ	100 mW	0603	Standard Part	
63	2	R31, R33	Resistor, 1%	100 kΩ	100 mW	0603	Standard Part	
64	1	R32	Resistor, 1%	2 Ω	100 mW	0603	Standard Part	
65	2	R34, R36	Resistor, 1%	100 Ω	100 mW	0805	Standard Part	
66	1	R35	Resistor, 1%	143 kΩ	100 mW	0603	Standard Part	
67	1	R42	Resistor, 1%	1 MΩ	100 mW	0603	Standard Part	
68	1	R44		DNP			Standard Part	
69	1	R45	Resistor, 1%	0 Ω	100 mW	1210	Standard Part	
70	1	R46	Resistor, 1%	0 Ω	100 mW	0805	Standard Part	
71	1	U1	ac-dc Converter	12 V	3 W		LS03-13B12R3	Mornsun America
72	1	U2	PFC Controller			SOIC-16	NCP1680AAD1R2G	Onsemi
73	2	U3, U6	GaN HEMT, 90 mΩ		650 V	QFN-5x7	TP44100SG	Tagore Technology
74	2	U4, U5	Gate Driver			SOIC-8	NCP51530BDR2G	Onsemi
75	1	PCB					TTPMH01901723	Tagore Technology

7 Schematic Diagram

The electrical schematic diagram of the EVB is as follows.



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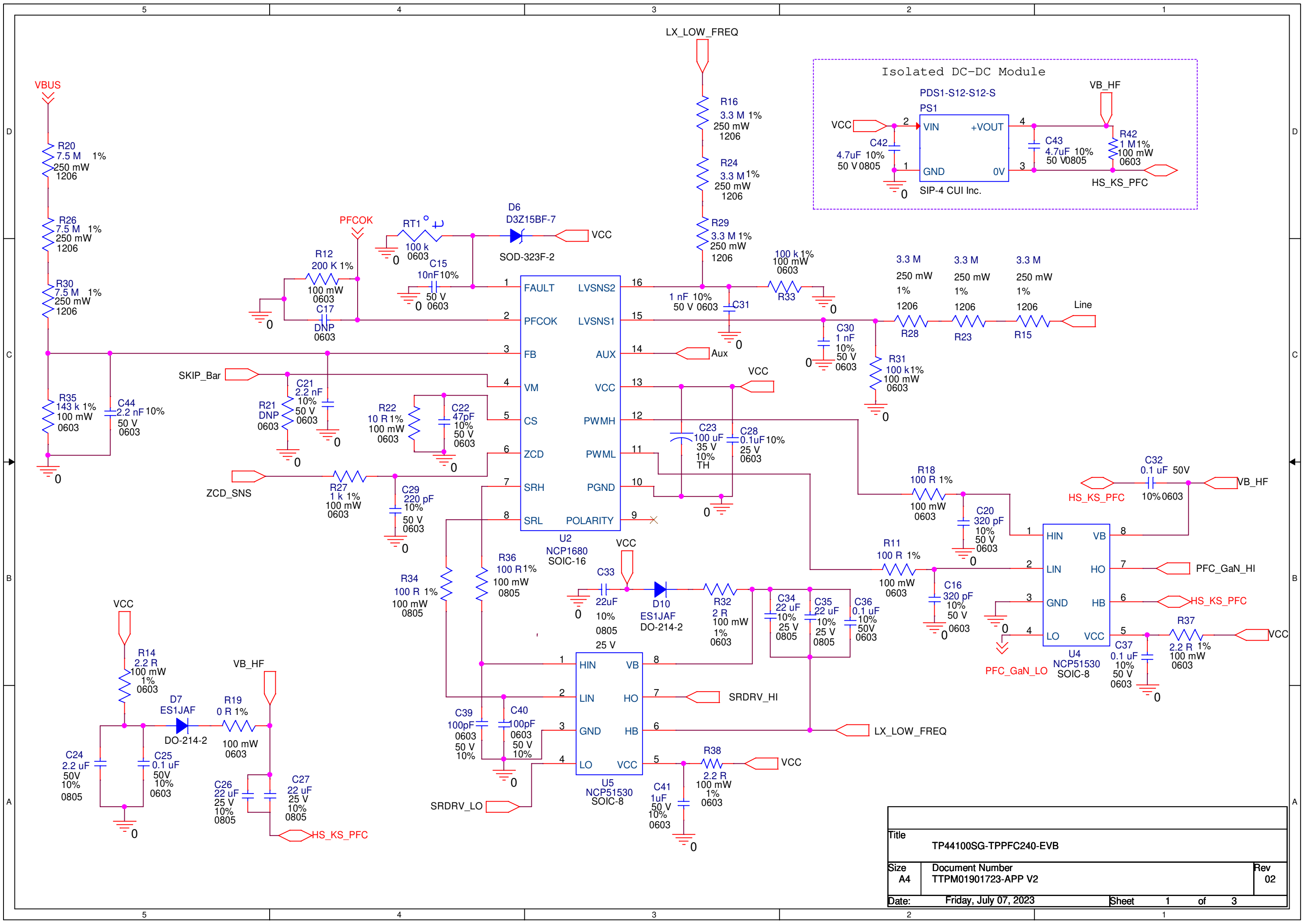
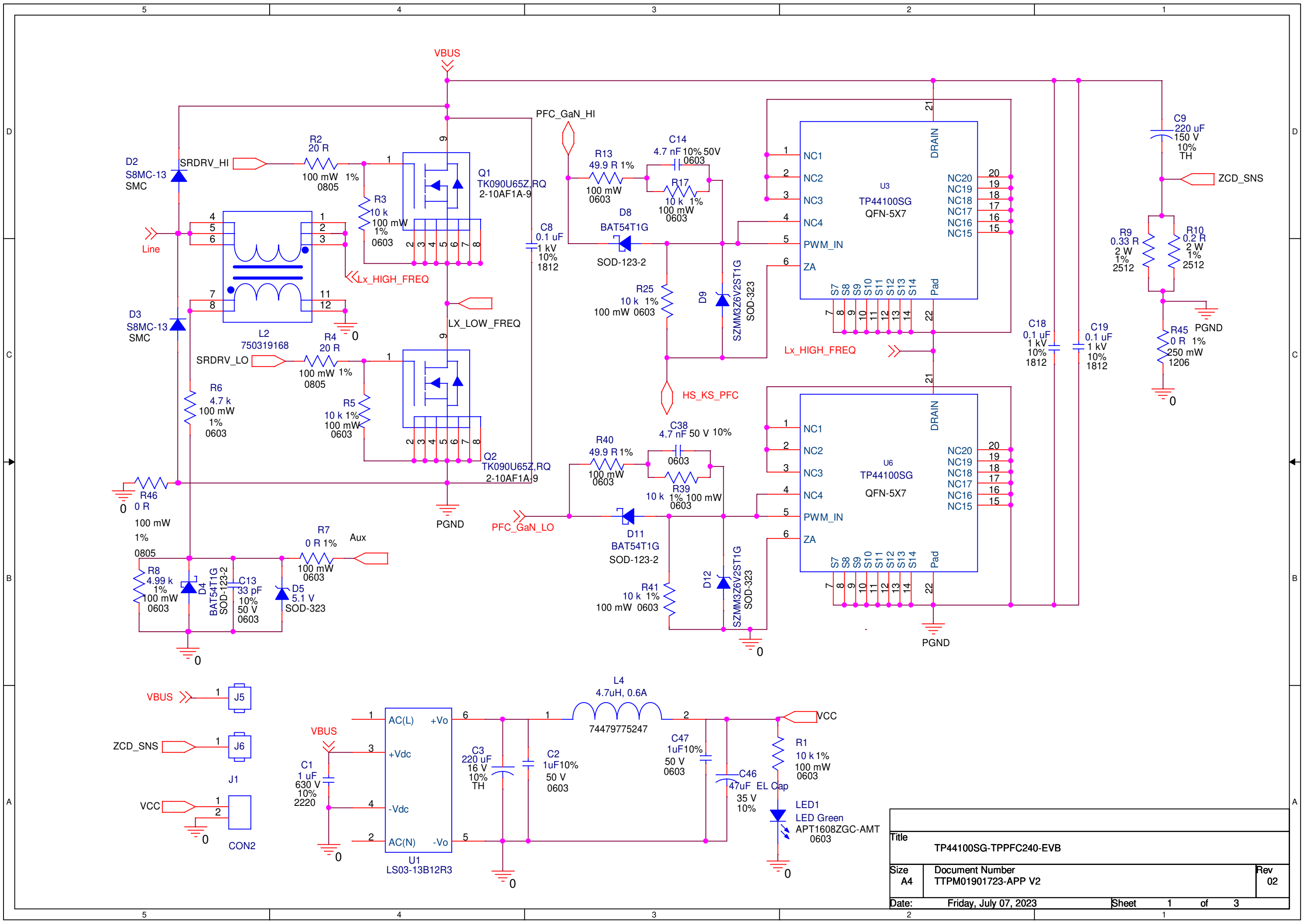
Size A4	Document Number TTPM01901723-APP V2	Rev 02
Date: Thursday, July 06, 2023	Sheet 1 of 3	



Title: TP44100SG-TPPFC240-EVB

Size: A4 | Document Number: TTPM01901723-APP V2 | Rev: 02

Date: Friday, July 07, 2023 | Sheet 1 of 3


VBUS
PFC_GaN_HI
D2
S8MC-13
SMC
SRDRV_HI
R2
20 R
100 mW 1%
0805
Q1
TK090U65Z,RQ
2-10AF1A-9
R3
10 k
100 mW
1%
0603
C8
0.1 uF
1 kV
10%
1812
Line
Lx_HIGH_FREQ
L2
750319168
D3
S8MC-13
SMC
SRDRV_LO
R4
20 R
100 mW 1%
0805
R5
10 k 1%
100 mW
0603
Q2
TK090U65Z,RQ
2-10AF1A-9
LX_LOW_FREQ
PGND
R6
4.7 k
100 mW
1%
0603
R46
0 R
100 mW
1%
0805
R7
0 R 1%
100 mW
0603
Aux
R8
4.99 k
1%
100 mW
0603
D4
BAT54T1G
SOD-123-2
C13
33 pF
10%
50 V
0603
D5
5.1 V
SOD-323
R13
49.9 R 1%
100 mW
0603
C14
4.7 nF 10% 50V
0603
R17
10 k 1%
100 mW
0603
D8
BAT54T1G
SOD-123-2
R25
10 k 1%
100 mW 0603
D9
SZMM3Z6V2ST1G
SOD-323
HS_KS_PFC
U3
TP44100SG
QFN-5X7
NC1
NC2
NC3
NC4
PWM_IN
ZA
DRAIN
NC20
NC19
NC18
NC17
NC16
NC15
S7 S8 S9 S10 S11 S12 S13 S14 Pad
Lx_HIGH_FREQ
R40
49.9 R 1%
100 mW
0603
C38
4.7 nF 50 V 10%
0603
R39
10 k 1% 100 mW
0603
PFC_GaN_LO
D11
BAT54T1G
SOD-123-2
R41
10 k 1%
100 mW 0603
D12
SZMM3Z6V2ST1G
SOD-323
U6
TP44100SG
QFN-5X7
C18
0.1 uF
1 kV
10%
1812
C19
0.1 uF
1 kV
10%
1812
C9
220 uF
150 V
10%
TH
ZCD_SNS
R9
0.33 R
2 W
1%
2512
R10
0.2 R
2 W
1%
2512
R45
0 R 1%
250 mW
1206
PGND
VBUS
J5
ZCD_SNS
J6
J1
VCC
CON2
C1
1 uF
630 V
10%
2220
U1
LS03-13B12R3
AC(L)
+Vdc
-Vdc
AC(N)
+Vo
-Vo
C3
220 uF
16 V
10%
TH
C2
1uF10%
50 V
0603
L4
4.7uH, 0.6A
74479775247
C47
1uF10%
50 V
0603
C46
47uF EL Cap
35 V
10%
VCC
R1
10 k 1%
100 mW
0603
LED1
LED Green
APT1608ZGC-AMT
0603
Title
TP44100SG-TPPFC240-EVB
Size
A4
Document Number
TTPM01901723-APP V2
Rev
02
Date:
Friday, July 07, 2023
Sheet 1 of 3