

240 W UHD Power Supply - CrM Totempole PFC and Current Mode LLC HB Solution

TND6457/D

onsemi's Devices	Applications	Input Voltage	Output Power	Topology	I/O Isolation
NCP1680 NCP13994 2*NCP51530BMNTWG 2*NCP4306DAHZZAASNT1G 2*NCP58921 2*NCP58922 2*NTMT064N65S3H 2*FDMS4D0N12C	PD3.1 multi-port adapter, industrial and other applications	90 Vac to 264 VAc	240 W	TPPFC + LLC	Isolated

	Output Specification
Output Voltage	48 V
Max Current	5 A
Min Current	zero

Efficiency	95.75% & 96.49% @ 115 Vac & 230 Vac and 48 V 5 A
Protection	OVP, OCP, SCP, OTP
PCBA	89 mm × 53 mm × 21 mm

Circuit Description

This reference design describes a 240 W **Ultra High Density(UHD)** power supply solution using NCP1680, NCP13994 and NCP4306 with TPPFC plus LLC power supply with 48 V 5 A for multi-port super charger, and general power supply supporting 240 W with high efficiency and compact profile.

The featured PFC solution uses NCP1680 totem pole PFC controller with CRM and VSFF control, HF current mode LLC controller NCP13994 and syn. controller NCP4306 for 48 V 5 A. 2 SJ FETs are used for PFC slow leg SW and 2 drive GaN NCP58921 are used for PFC fast leg SW and 2 drive GaN NCP58922 for LLC converter.

This reference design provides a total solution which has the whole circuit schematic details, PCB layout, EVM photo, inductor, transformer specification and BOM for 240 W UHD power supply solution, also some key waveforms for reference.

A dual layer PCB is designed in order to reduce cost for a demonstration although totem pole PFC has more component and complex replacement, also consider easy to test, only 1 daughter card with some filtering components is used.

LLC controller has a high startup current source and PFC controller has a low operation current, so LLC startup

current source should supply PFC and LLC Vcc during startup, PFC controller has a low Vcc_on threshold so PFC will start first then LLC Vcc continues to rise to Vcc_on threshold, PFC has completed startup and PFCOK signal has a high level output while Vcc reaches Vcc_on, a capacitor with large capacitance is used for LLC Vcc to maintain enough voltage to ensure PFC operation until LLC operation then LLC's auxiliary winding supplies all Vcc voltage.

The PFCOK pin is intended to control operation of a downstream DC – DC converter by acting as an enable or UVLO signal. The pin output of the pin is a current source proportional to the FB pin voltage with a gain of 10 _A/V. A resistor to ground placed at the pin will give the downstream converter an image of the bulk voltage for use as a UVLO or brown out for LLC converter, this will reduce the power loss on bulk voltage resistor divider.

Two auxiliary windings are used for primary and secondary. 2 pcs NCP4306 with TSOP6 dedicated for LLC are used for secondary rectified controller, compared with dual channel syn. controller, the PCB replacement and layout can be optimized.

TND6457/D

Key Features

- AC input from 90 V to 264 V
- TPPFC + LLC topology
- High Frequency operation with GaN, 50 mΩ for TPPFC and 78 mΩ for LLC
- Output voltage and current: 48 V and 5 A
- Max Output power: 240 W
- Low standby power: <300 mW in universal
- Ripple&Noise: <150 mV
AVG efficiency: 94.25% & 94.76%
at 115 Vac & 230 Vac and 48 V
- Full load efficiency: 95.75% & 96.49%
at 115 Vac & 230 Vac and 48 V 5 A
- OVP, OCP and SCP protection
- Open loop protection
- 2 layers PCB used and name card size with compact design
- PCBA size: 89 mm × 53 mm × 21 mm
- Power Density: 39.7 W/in³

BOARD PHOTOS

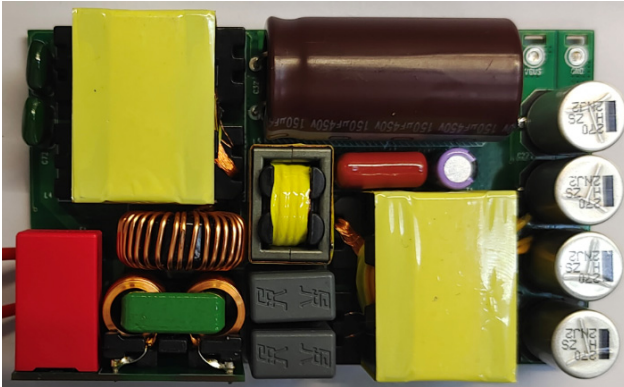


Figure 1. The Front View of 240 W EVM

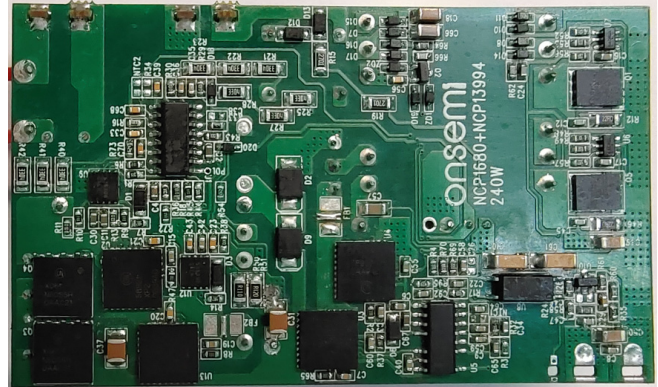


Figure 2. Reverse Side of 240 W EVM

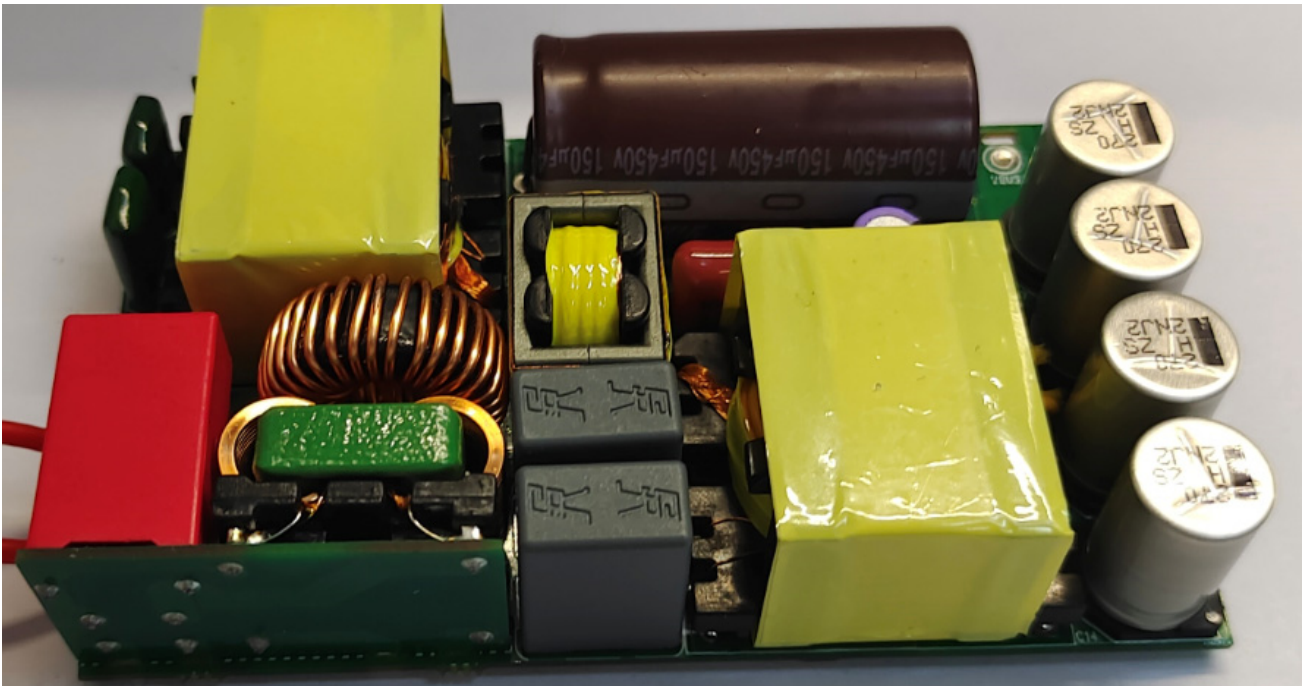


Figure 3. Profile of 240 W EVM

TND6457/D

CIRCUIT SCHEMATIC (TPPFC PORTION)

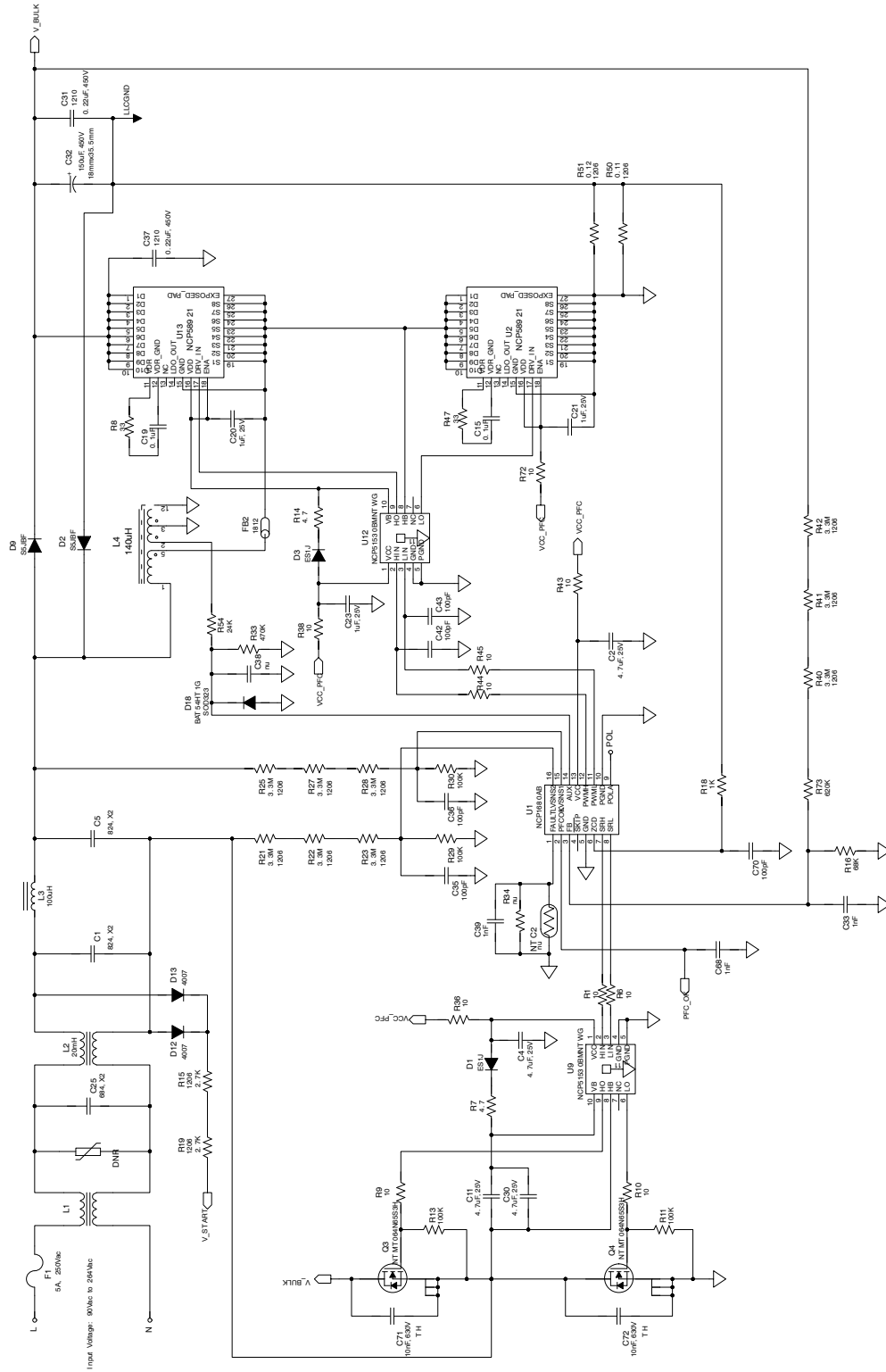


Figure 4. Schematic for TPPFC Portion

CIRCUIT SCHEMATIC (LLC PORTION)

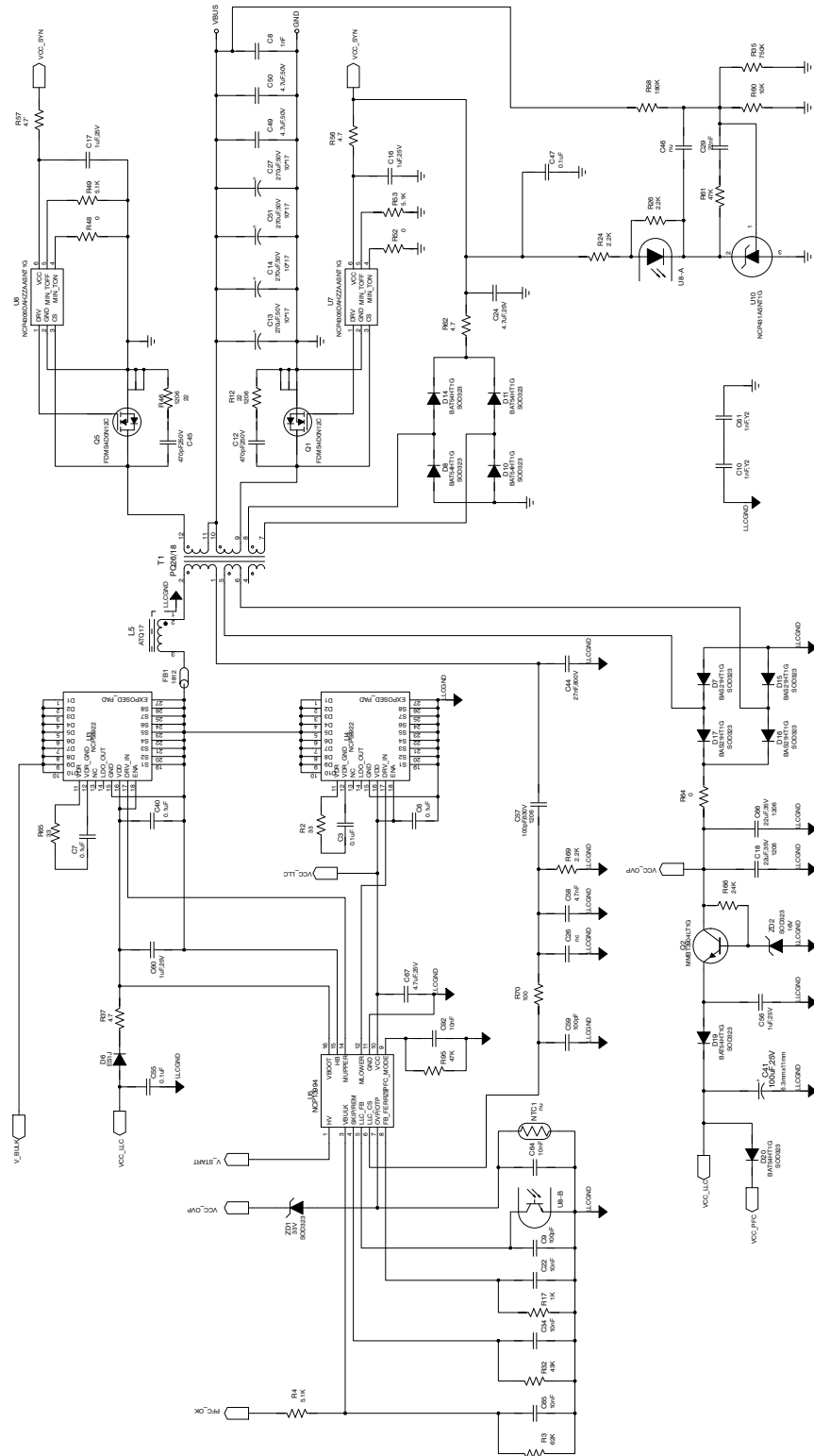


Figure 5. Schematic for LLC

PCB LAYOUT



PFC INDUCTORS DESIGNS

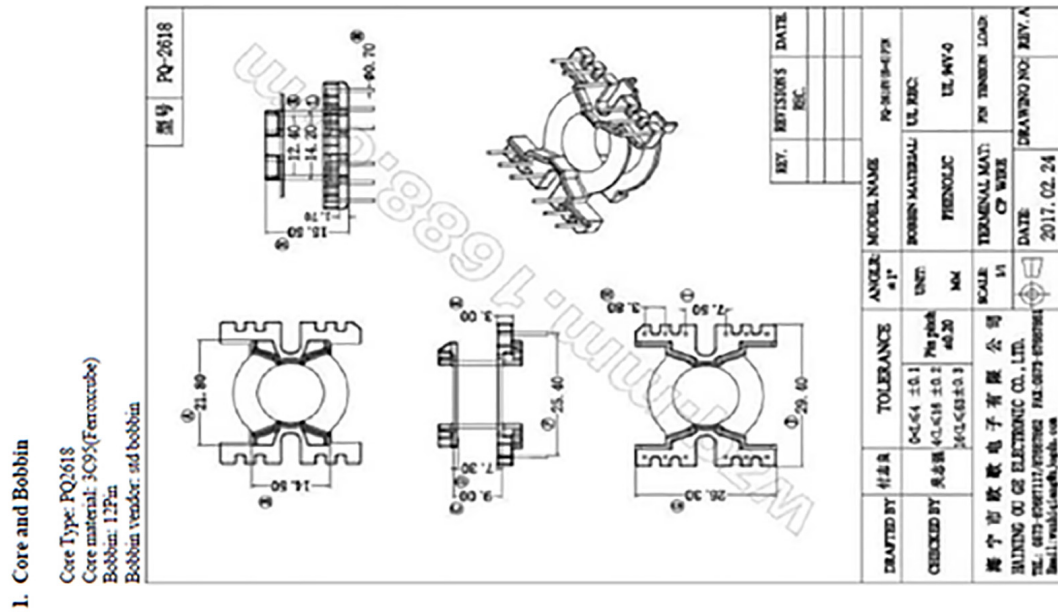
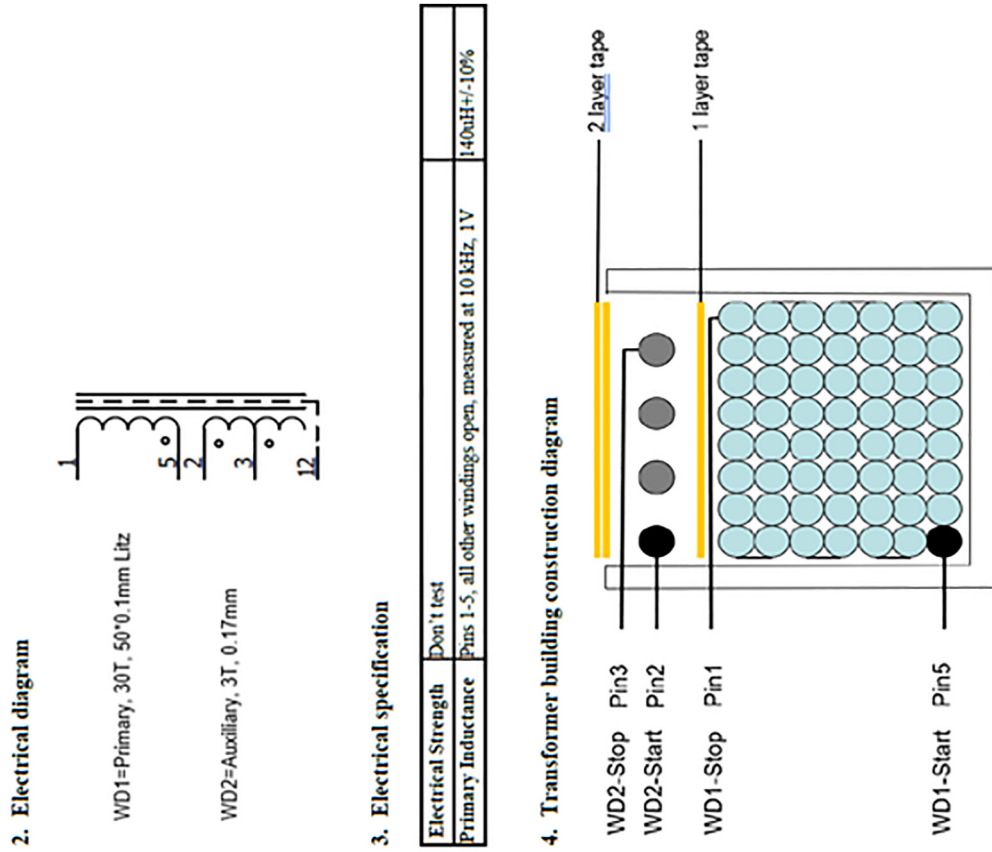


Figure 8. PFC Inductor Specification

LLC RESONANT INDUCTORS DESIGNS

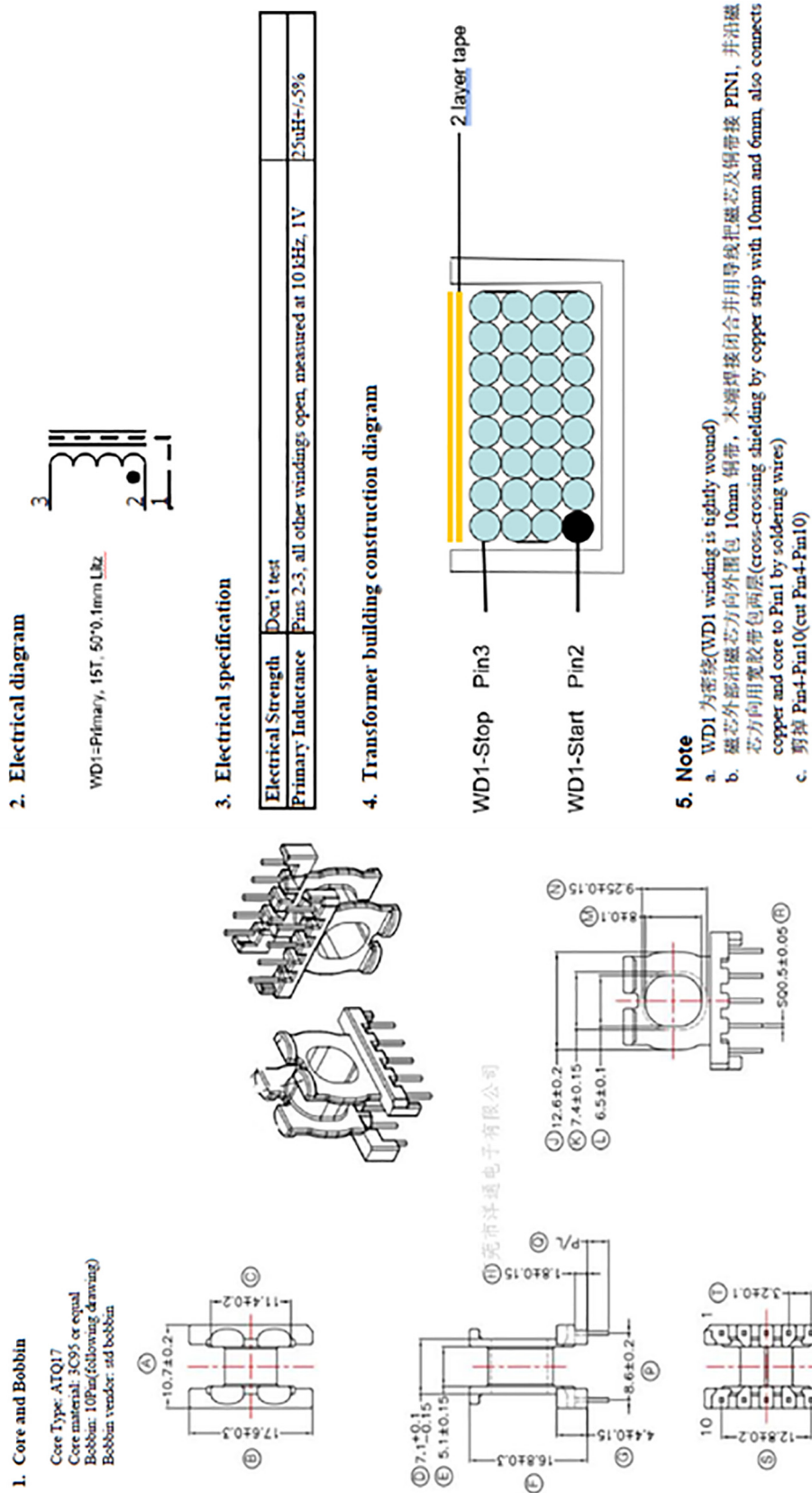


Figure 9. LLC Resonant Inductor Specification

WD1=Polyurea, 11T, 2x25'0 1mm L₂, 3 layers
WD2=Auxiliary, 2T, 6 & 12mm
WD3=Output
3T, 2x40'0 1mm triple isolated L₂ wro, 1 layer
WD4=Output
3T, 2x40'0 1mm triple isolated L₂ wro, 1 layer
WD5=Output
1T, 0.2mm triple isolated wro

Electrical Strength	Pins 1, 2, 4, 5, 6 to Pin 7-12	3000V
Primary Inductance	Pins 1-2, all other windings open, measured at 10kHz, 1V	150uH +/-5%

The diagram illustrates a 16-pin ribbon cable connector with the following pin assignments and tape layer counts:

- Pin 1:** WD1-Start (1 layer tape)
- Pin 2:** WD1-Stop (1 layer tape)
- Pin 3:** WD2-Start (1 layer tape)
- Pin 4:** WD2-Stop (1 layer tape)
- Pin 5:** WD3-Start (1 layer tape)
- Pin 6:** WD3-Stop (1 layer tape)
- Pin 7:** WD4-Start (1 layer tape)
- Pin 8:** WD4-Stop (1 layer tape)
- Pin 9:** WD5-Start (3 layer tape)
- Pin 10:** WD5-Stop (3 layer tape)
- Pin 11:** WD6-Start (3 layer tape)
- Pin 12:** WD6-Stop (3 layer tape)
- Pin 13:** WD7-Start (3 layer tape)
- Pin 14:** WD7-Stop (3 layer tape)
- Pin 15:** WD8-Start (3 layer tape)
- Pin 16:** WD8-Stop (3 layer tape)

The diagram also shows a red line indicating a "Cut, No wire out" point between Pin 10 and Pin 11.

- a. WD1, WD2, WD3 为一层密绕, WD4, WD5 绕组为一层疏绕(WD1, WD2, WD3 是 tightly wound, WD4, WD5 is spreading wound).
- b. 磁芯外部缠绕线方向包一圈 6mm 宽铜带, 沿磁芯方向外围包 10mm 铜带, 末端焊接闭合并用导线固定磁芯及两个铜带接 Pin4, 并沿磁芯方向用 20mm 宽胶带包两层(cross-crossing shelding by copper strip with 14mm and 6mm, also connects copper and core to Pin4 by soldering wires, and 2 layer tape with 2.2mm width or more is wound following core direction)
- 将焊 Pin3(cut Pin3)

Core Type: PQ2618
Core material: Ferroxcube 3C95
Bobbin: 12Pin
Bobbin vendor: std bobbin

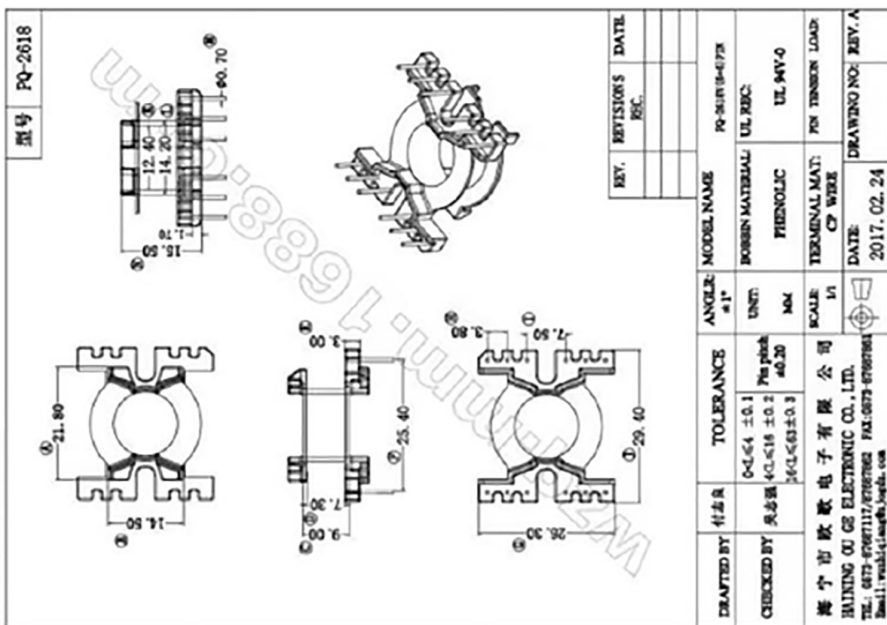


Figure 10. LLC Transformer Specification

Standby Power and PF

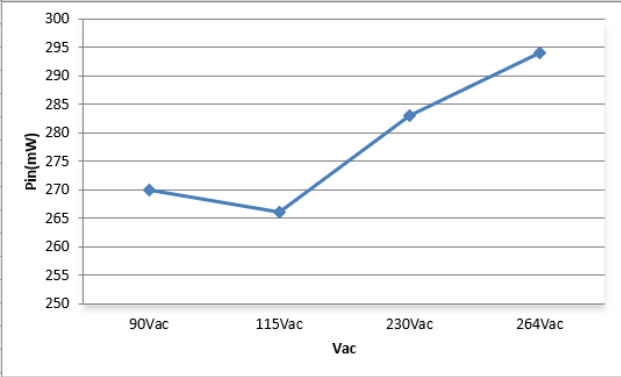


Figure 11. Standby Power

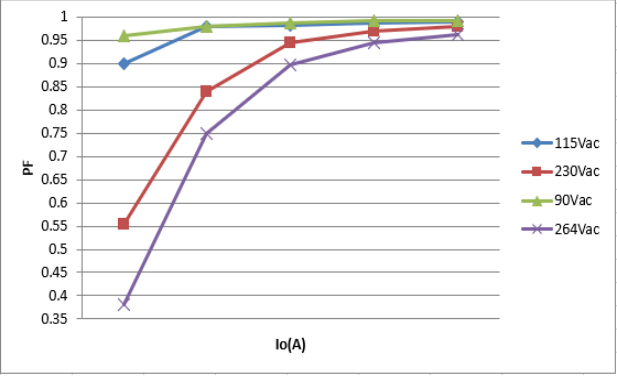


Figure 12. PF

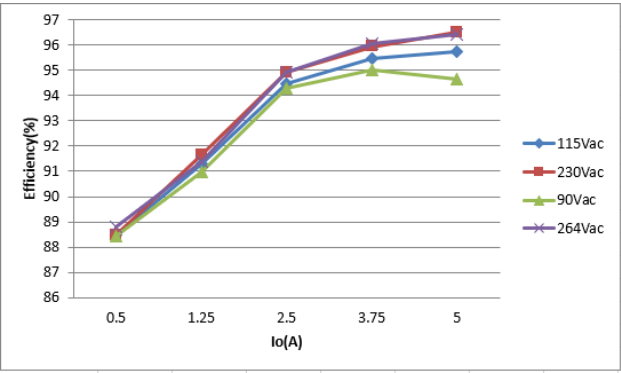


Figure 13. Efficiency vs. Load

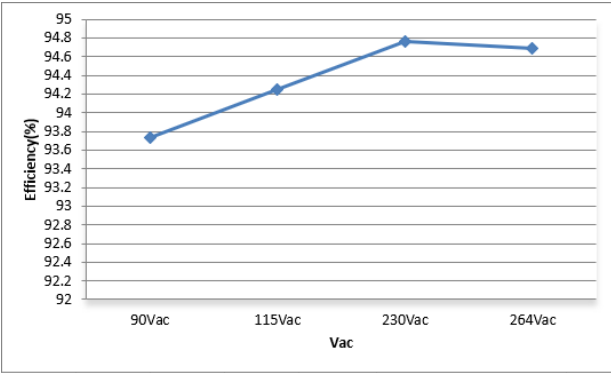


Figure 14. AVG Efficiency

PFC Waveform at 90 Vac and Full Load

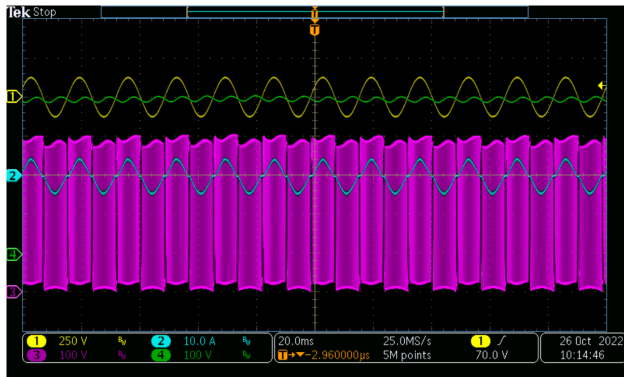


Figure 15. 90 Vac and Full Load
(ch1-Vin, ch2-Iin, ch3-fast leg SW, ch4-Vbulk)

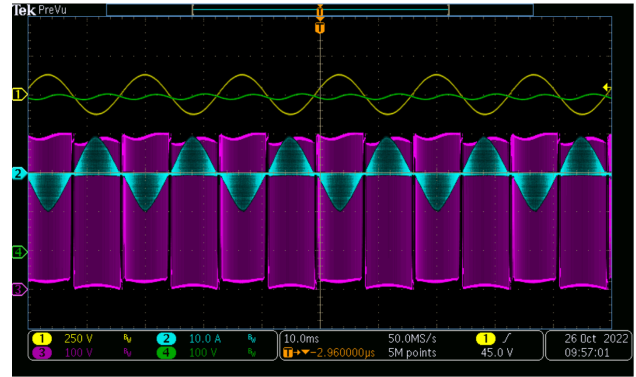


Figure 16. 90 Vac and Full Load
(ch1-Vin, ch2-IL, ch3-fast leg SW, ch4-Vbulk)

PFC Waveform at 90 Vac and Full Load

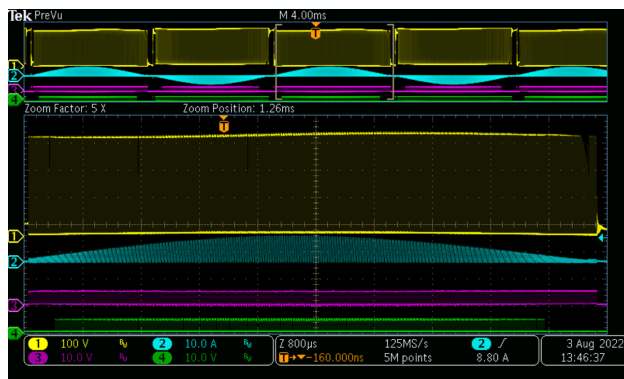


Figure 17. 90 Vac and Full Load
(ch1-Vfastleg, ch2-IL, ch3-Vpwml, ch4-Vpwmh)

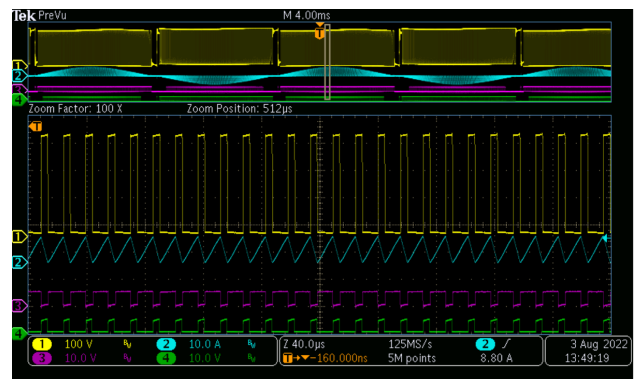


Figure 18. 90 Vac and Full Load
(ch1-Vfastleg, ch2-IL, ch3-Vpwml, ch4-Vpwmh)

Load Transition

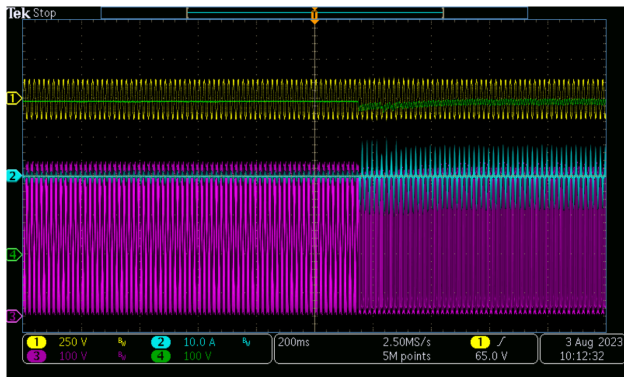


Figure 19. 0 to Full Load Transition at 90 Vac
(ch1-Vin, ch2-IL, ch3-Vfast leg SW, ch4-Vbulk)

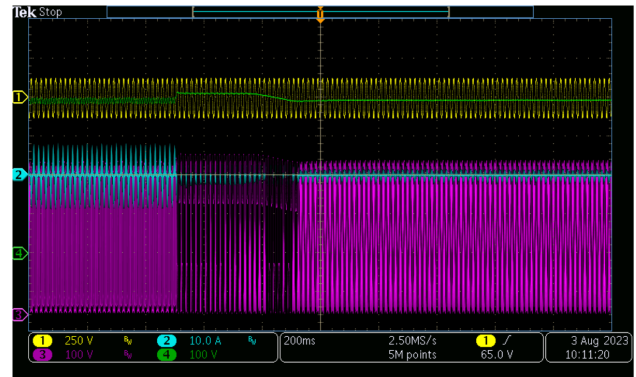


Figure 20. Full Load to 0 Transition at 90 Vac
(ch1-Vin, ch2-IL, ch3-Vfast leg SW, ch4-Vbulk)

Line Transition

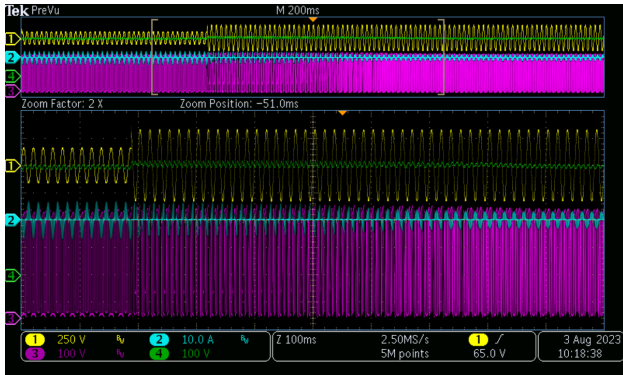


Figure 21. 115 Vac to 230 Vac Transition at Full Load (ch1-Vin, ch2-IL, ch3-Vfast leg SW, ch4-Vbulk)

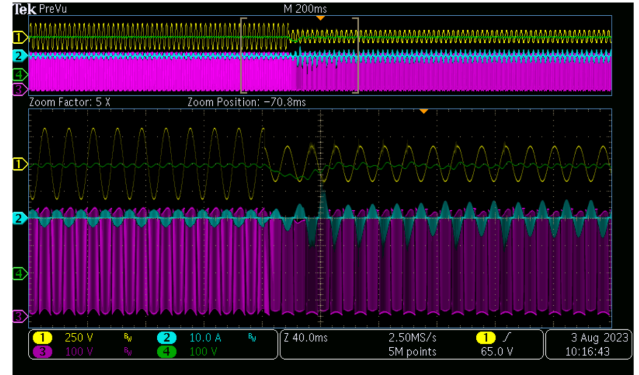


Figure 22. 230 Vac to 115 Vac Transition at Full Load (ch1-Vin, ch2-IL, ch3-Vfast leg SW, ch4-Vbulk)

LLC Startup Waveform at No Load and Full Load

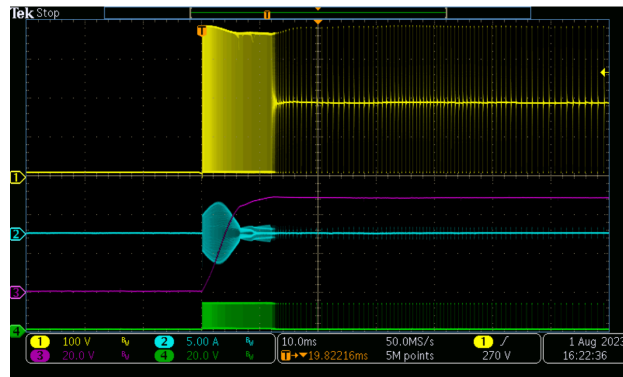


Figure 23. Power on at 115Vac and 48 V 0 A (ch1-Vllcsw, ch2-Ip, ch3-Vo, ch4-Vmlower)

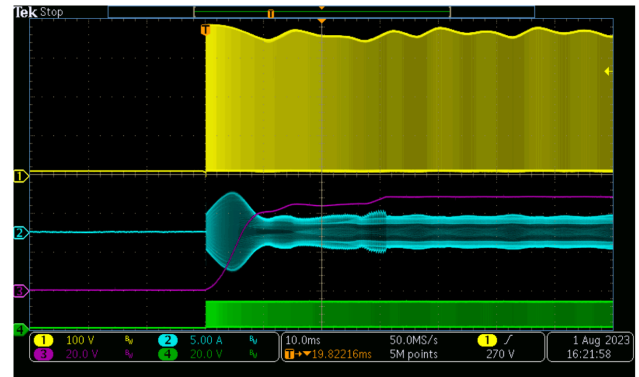


Figure 24. Power on at 115Vac and 48 V 5 A (ch1-Vllcsw, ch2-Ip, ch3-Vo, ch4-Vmlower)

LLC Operation Waveform and Max Dead Time

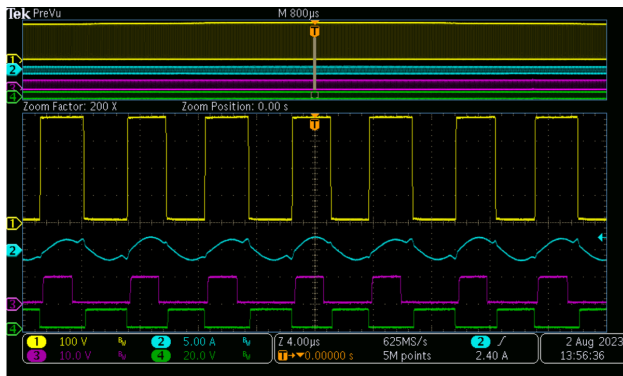


Figure 25. Stable Operation at 115 Vac and 48 V 5 A (ch1-Vllcsw, ch2-Ip, ch3-Vsyn-driv, ch4-Vmlower)

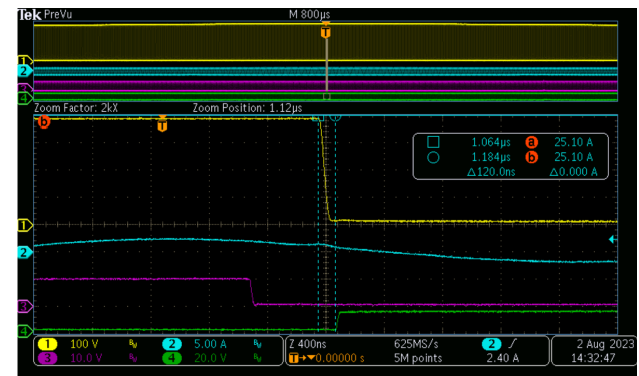


Figure 26. Stable Operation at 115 Vac and 48 V 5 A (ch1-Vllcsw, ch2-Ip, ch3-Vsyn-driv, ch4-Vmlower)

Secondary Stress

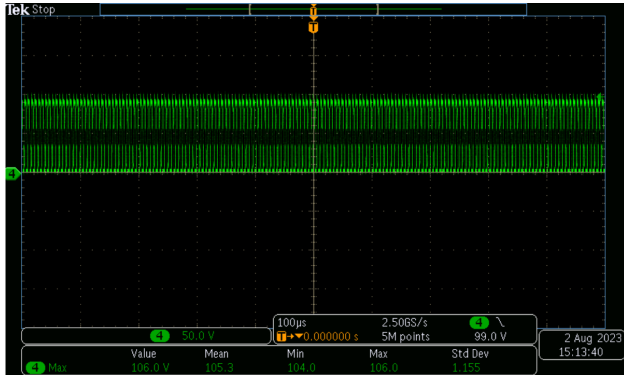


Figure 27. Normal operation at 115 Vac and 48 V & 5 A
(ch4-Vsecondary-vds)

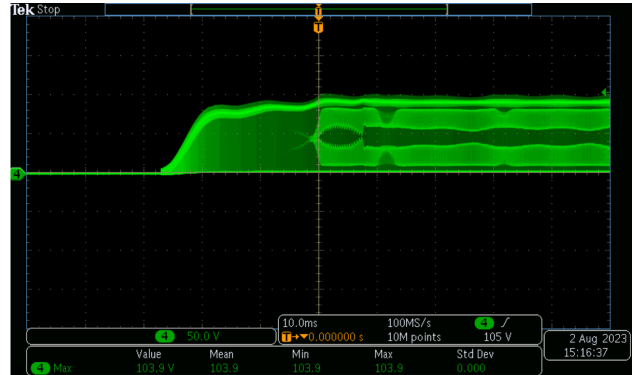


Figure 28. Startup at 115 Vac and 48 V & 5 A
(ch4-Vsecondary-vds)

LLC Operation Waveform During Load Transition

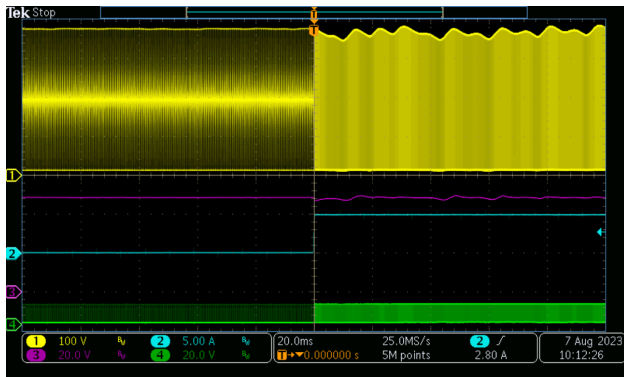


Figure 29. 0-5 A Load Transition at 48 V
(ch1-Vllc-sw, ch2-lo, ch3-Vo, ch4-Vsyn-drv)

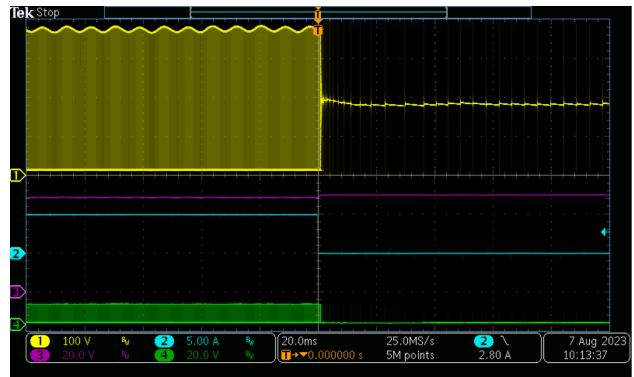


Figure 30. 5 A-0 Load Transition at 48 V
(ch1-Vllc-sw, ch2-lo, ch3-Vo, ch4-Vsyn-drv)

LLC Operation Waveform at Skip Mode

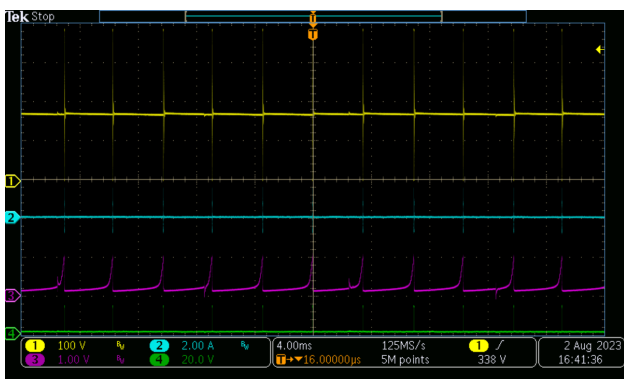


Figure 31. Waveform at 115 Vac and 48 V 0 A
(ch1-Vllc-sw, ch2-lp, ch3-Vfb, ch4-Vldrv)



Figure 32. Waveform at 115 Vac and 48 V 0.5 A
(ch1-Vllc-sw, ch2-lp, ch3-Vfb, ch4-Vldrv)

Startup Timing at No Load and Full Load

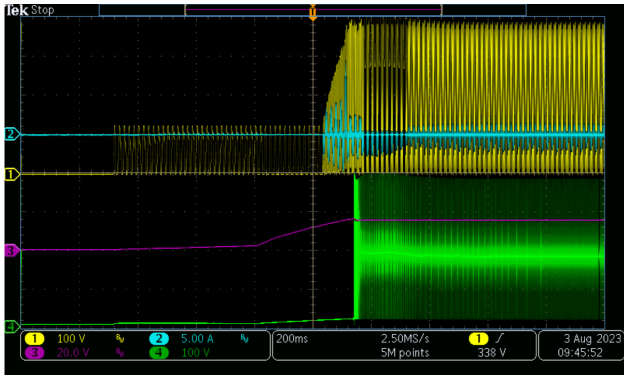


Figure 33. Startup at 115 Vac and 48 V 0 A
(Ch1-Vpfc-fastleg, ch2-pfc-ILch3-Vcc_llc,
ch4-Vsw-llc)

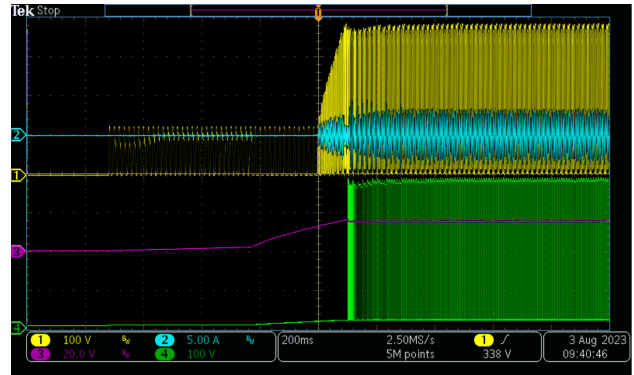


Figure 34. Startup at 115 Vac and 48 V 5 A
(Ch1-Vpfc-fastleg, ch2-pfc-ILch3-Vcc_llc,
ch4-Vsw-llc)

Ripple Test

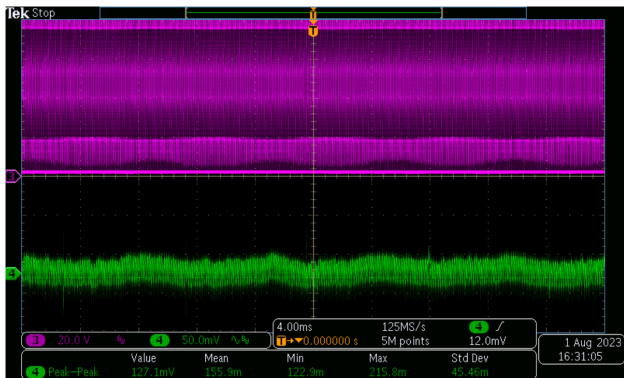


Figure 35. 115 V and 48 V 0.9 A
(ch3-Vds-sec, ch4-Vripple)

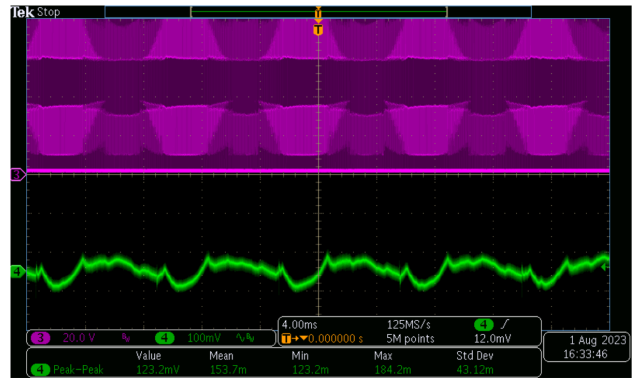


Figure 36. 115 Vac and 48 V 5 A
(ch3-Vds-sec, ch4-Vripple)

Load Dynamic Response

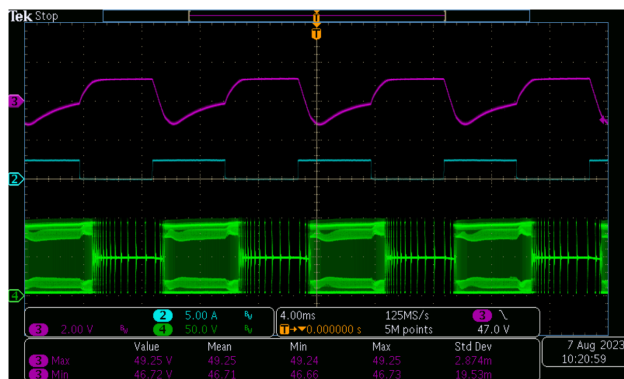


Figure 37. 0-2.5 A, 10 mS Cycle, 0.25 A/μs
(ch2-Io, ch3-V0, ch4-Vsecds-llc)

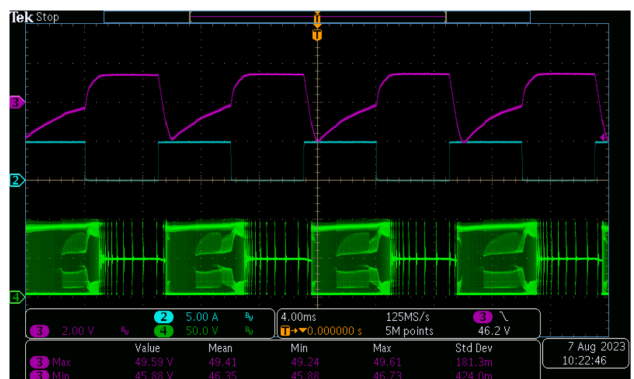


Figure 38. 0-5 A, 10 mS Cycle, 0.25 A/μs
(ch3-Vds-sec, ch4-Vripple)

OCP Waveform

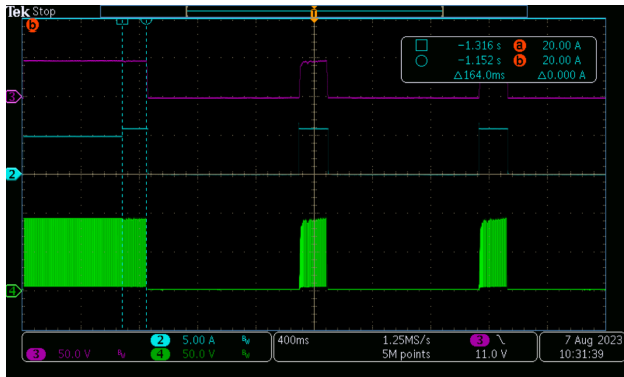


Figure 39. OCP at 115 Vac and 48 V 5.8 A to 6 A Transition (ch2-lo, ch3-Vo, ch4-Vds-sec)

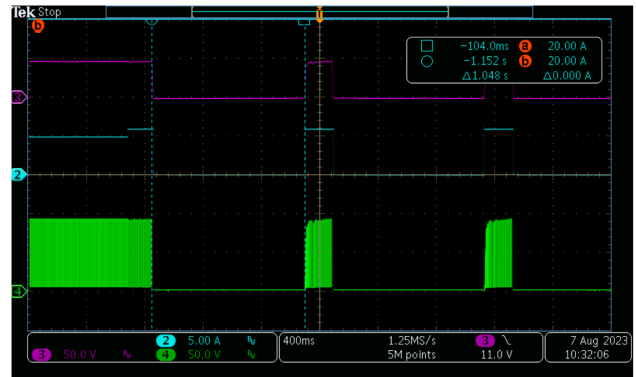


Figure 40. OCP at 115 Vac and 48 V 5.8 A to 6 A Transition (ch2-lo, ch3-Vo, ch4-Vds-sec)

Thermal Camera Image (Tested after 30 min Operation)

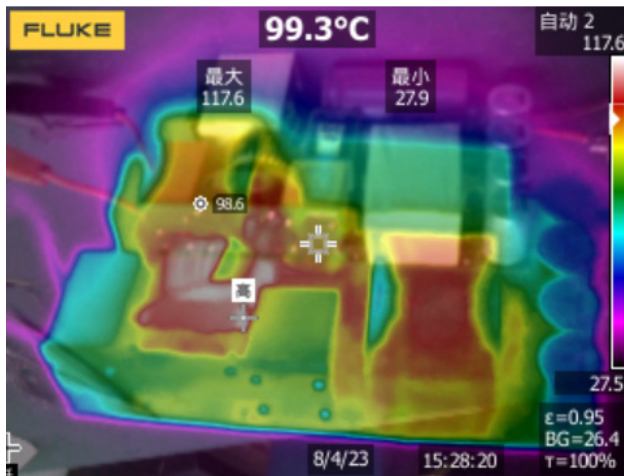


Figure 41. 90 Vac & 48 V 5 A, Front Side

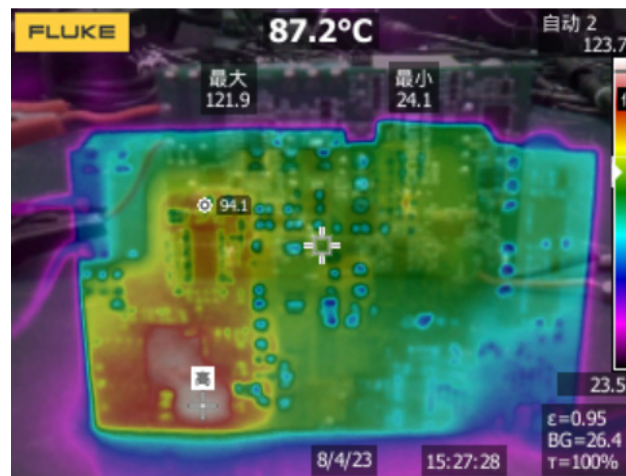


Figure 42. 90 Vac & 48 V 5 A, Reverse Side

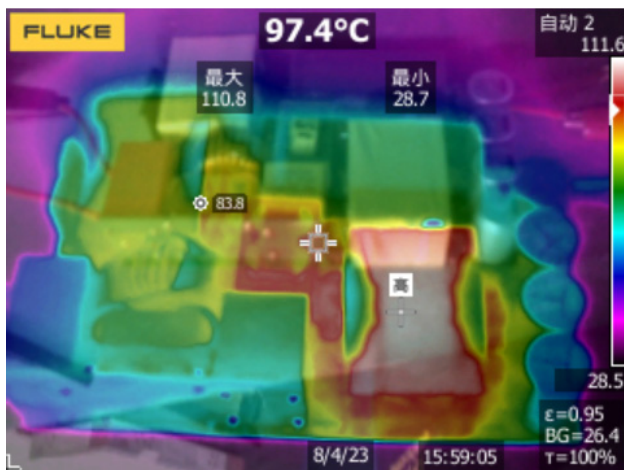


Figure 43. 115 Vac & 48 V 5 A, Front Side

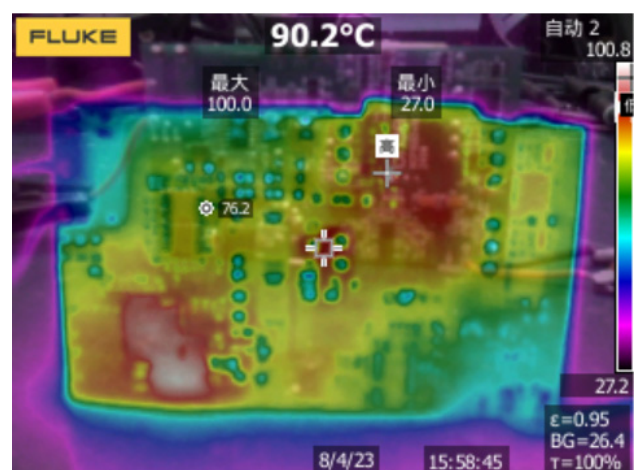


Figure 44. 115 Vac & 48 V 5 A, Reverse Side

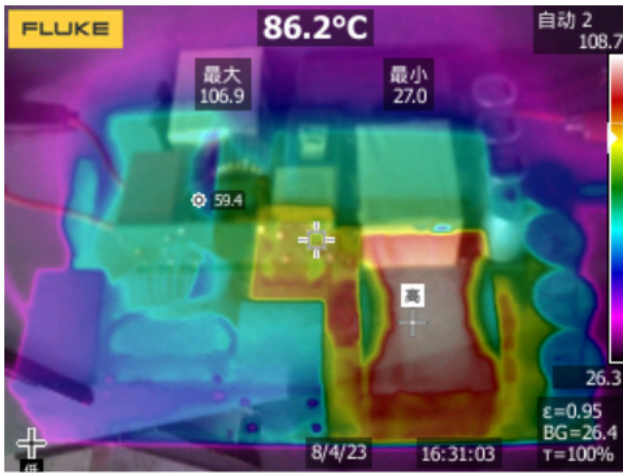


Figure 45. 230 Vac & 48 V 5 A, Front Side

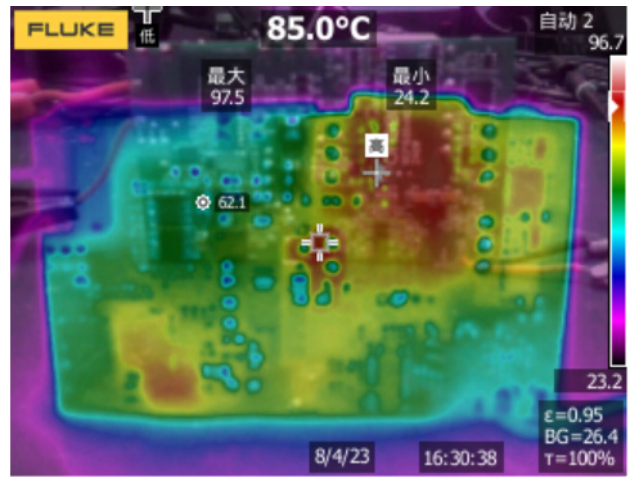


Figure 46. 230 Vac & 48 V 5 A, Reverse Side

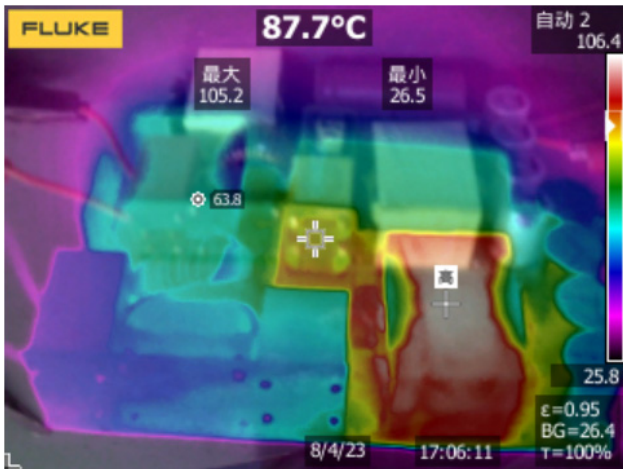


Figure 47. 264 Vac & 48 V 5 A, Front Side

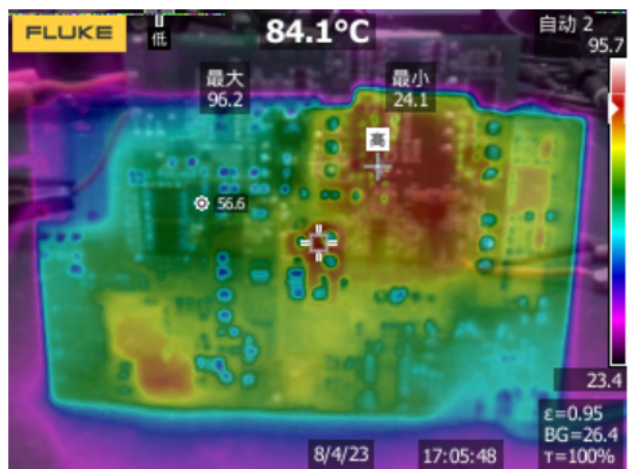


Figure 48. 264 Vac & 48 V 5 A, Reverse Side

Table 1. BOM

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
1	1	L5	Inductor	ATQ17	TH type	Std	25 μ H	ATQ17, 10Pin
2	8	C3 C6-7 C15 C19 C40 C47 C55	Ceramic Capacitor	/885012206095	603	Wurth	0.1 μ F	Capacitor, Ceramic, 50 V, 10%
3	2	C31 C37	Ceramic Capacitor	C3225X7T2W224K	1210	TDK	0.22 μ F, 450 V	Capacitor, Ceramic, Chip, 10%
4	7	C9 C35-36 C42-43 C59 C70	Ceramic Capacitor	/885012206077	603	Wurth	100 pF	Capacitor, Ceramic, 50 V, 10%
5	1	C57	Ceramic Capacitor	/885342008004	1206	Wurth	100 pF, 630 V	Capacitor, Ceramic, SMD, 5%
6	5	C22 C34 C64-65 C92	Ceramic Capacitor	/885012206089	603	Wurth	10 nF	Capacitor, Ceramic, 50 V, 10%
7	2	C71-72	Ceramic Capacitor	CL112J103J050	TH	KYET	10 nF, 630 V	Capacitor, Ceramic, TH, 5%
8	4	C8 C33 C39 C68	Ceramic Capacitor	/885012206083	603	Wurth	1 nF	Capacitor, Ceramic, 50 V, 10%
9	2	C10 C61	Ceramic Capacitor	/8853522100131	1808	Wurth	1 nF, Y2	HV Ceramic Capacitor, safety standard approved, 10%
10	7	C16-17 C20-21 C23 C56 C60	Ceramic Capacitor	/885012206076	603	Wurth	1 μ F, 25 V	Capacitor, Ceramic, 25 V, 10%
11	1	C29	Ceramic Capacitor	/885012206091	603	Wurth	22 nF	Capacitor, Ceramic, 50 V, 10%
12	2	C18 C66	Ceramic Capacitor	C3216X5R1V226MTJ00E	1206	TDK	22 μ F, 35 V	Capacitor, Ceramic, 35 V, 20%
13	1	C44	Film Capacitor	ECWH8273HA	THT, 12.5 mm, 15 mm $\times$ 6 mm $\times$ 12 mm	Panasonic	27 nF, 800 V	Film capacitor
14	1	C58	Ceramic Capacitor	/885012206087	603	Wurth	4.7 nF	Capacitor, Ceramic, 50 V, 10%
15	6	C2 C4 C11 C24 C30 C67	Ceramic Capacitor	C1608X5R1E475K080AC	603	TDK	4.7 μ F, 25 V	Capacitor, Ceramic, 25 V, 10%
16	2	C49-50	Ceramic Capacitor	GRM31CR71H475KA12L	1206	Murata	4.7 μ F, 50 V	Capacitor, Ceramic, 50 V, 10%
17	2	C12 C45	Ceramic Capacitor	/885342006005	603	Wurth	470 pF, 250 V	Capacitor, Ceramic, SMD, 5%
18	2	C1 C5	X2 Capacitor	SP2824K32CKR6LC	THT, 10 mm, 12.5 mm $\times$ 6 mm $\times$ 16 mm	SRD	824, X2	X2 capacitor, Safety standard approved, 10%
19	1	C25	X2 Capacitor	X2 684K310V	THT, 10 mm, 12.5 mm $\times$ 6 mm $\times$ 20 mm	JURCC	684, X2	X2 capacitor, Safety standard approved, 10%
20	1	C26	Ceramic Capacitor	/885012206087	603	Wurth	nc	nc
21	2	C38 C46	Ceramic Capacitor	/885012206095	603	Wurth	nc	nc
22	2	D2 D9	Rectifier	S5JBF	SMBF	SHIKUES	5 A, 600 V	General Rectifier
23	1	DNR	Varistor	SVMH4532KA301PT401	3225	Shunlord	470 V	Varistor, 471 V
24	2	D12-13	Standard rectifier	4007	SOD123FL	Std	0.8 A, 600 V	General Rectifier, 0.8 A, 600 V
25	3	D1 D3 D6	Ultrafast rectifier	ES1JFL	SOD123FL	onsemi	1 A, 600 V	Ultrafast Rectifier, 1 A, 600 V
26	4	D7 D15-17	Switching diode	BAS21HT1G	SOD323	onsemi	0.2 A, 250 V	Switching diode, SMD
27	7	D8 D10-11 D14 D18-20	Switching diode	BAT54HT1G	SOD323	onsemi	0.2 A, 30 V	Switching diode, SMD

TND6457/D

Table 1. BOM (continued)

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
28	2	FB1-2	Ferrite bead	PZ3216U600-4R0TF	1206	Shunlord	nc	nc
29	1	L1	Common filter	Toroidal CM filter	TH	Std	500 μ H	T type, 10*6*5 MnZn core, 7T, 0.7 mm wire
30	1	L2	Common filter	SQ1515	TH, 17 mm $\times$ 13 mm	Std	20 mH	CM Filter, SQ1515, 17*13, 60 m Ω
31	1	F1	Fuse	39215000000	Axial lead	Littlefuse	5 A, 250 Vac	Micro Fuse, 5 A/250 V
32	1	Q2	NPN Transistor	MMBT3904LT1G	SOT23	onsemi		GENERAL PURPOSE NPN SILICON TRANSISTOR
33	1	U10	Voltage reference	NCP431ACSNT1G	SOT23	onsemi		PROGRAMMABLE PRECISION REFERENCE
34	1	U1	TPPFC controller	NCP1680AB	SO16	onsemi		TPPFC controller
35	1	U5	LLC controller	NCP13994	SO16	onsemi		
36	2	U2 U13	Drive GaN	NCP58921	QFN26	onsemi	50 m Ω	
37	2	U3-4	Drive GaN	NCP58922	QFN26	onsemi	78mohm	
38	2	U6-7	Syn. rectified controller	NCP4306DAHZZAAS-NT1G	TSOP6	onsemi		
39	2	U9 U12	HB Drive	NCP51530BMNTWG	DFN10	onsemi		
40	2	Q1 Q5	MOSFET	FDMS4D0N12C	SO8FL	onsemi		MOSFET, NChan, 120 V
41	2	Q3-4	MOSFET	NTMT064N65S3H	Power88	onsemi		MOSFET, NChan, 650 V
42	2	NTC1-2	NTC	SD-NT1608X104J4250HTF	603	Sunlord	nc	
43	1	U8	Optical coupler	FODM1009	LSOP4	onsemi		optical coupler, standard SOP package
44	1	L3	Toroidal Line Choke	T065125-100uH-0.9	TH type	Std	100 μ H	FeSiAl Toroidal, 65125, 0.9 mm wire
45	1	L4	Inductor	PQ2618	TH type	Std	140 μ H	PQ2618, Ferroxcube 3C95 core,12 Pin Bobbin
46	1	T1	Transformer	PQ2618	TH type	Std	150 μ H	PQ2618, Ferroxcube 3C95 core,12 Pin Bobbin
47	3	R48 R52 R64	Resistor	Std	603	Std	0	Resistor, Chip, 1/10 W, 1%
48	10	R1 R6 R9-10 R36 R38 R43-45 R72	Resistor	Std	603	Std	10	Resistor, Chip, 1/10 W, 1%
49	1	R70	Resistor	Std	603	Std	100	Resistor, Chip, 1/10 W, 1%
50	4	R11 R13 R29-30	Resistor	Std	603	Std	100 K	Resistor, Chip, 1/10 W, 1%
51	1	R60	Resistor	Std	603	Std	10 K	Resistor, Chip, 1/10 W, 1%
52	1	R58	Resistor	Std	603	Std	180 K	Resistor, Chip, 1/10 W, 1%
53	2	R17-18	Resistor	Std	603	Std	1 K	Resistor, Chip, 1/10 W, 1%
54	3	R24 R26 R69	Resistor	Std	603	Std	2.2 K	Resistor, Chip, 1/10 W, 1%
55	2	R54 R66	Resistor	Std	603	Std	24 K	Resistor, Chip, 1/10 W, 1%
56	4	R2 R8 R47 R65	Resistor	Std	603	Std	33	Resistor, Chip, 1/10 W, 1%
57	6	R7 R14 R37 R56 R57 R62	Resistor	Std	603	Std	4.7	Resistor, Chip, 1/10 W, 1%
58	1	R32	Resistor	Std	603	Std	43 K	Resistor, Chip, 1/10 W, 1%
59	1	R33	Resistor	Std	603	Std	470 K	Resistor, Chip, 1/10W, 1%

TND6457/D

Table 1. BOM (continued)

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
60	2	R61 R95	Resistor	Std	603	Std	47 K	Resistor, Chip, 1/10 W, 1%
61	3	R4 R49 R53	Resistor	Std	603	Std	5.1 K	Resistor, Chip, 1/10 W, 1%
62	1	R73	Resistor	Std	603	Std	620 K	Resistor, Chip, 1/10 W, 1%
63	1	R3	Resistor	Std	603	Std	62 K	Resistor, Chip, 1/10 W, 1%
64	1	R16	Resistor	Std	603	Std	68 K	Resistor, Chip, 1/10 W, 1%
65	1	R35	Resistor	Std	603	Std	750 K	Resistor, Chip, 1/10 W, 1%
66	1	R34	Resistor	Std	603	Std	nc	Resistor, Chip, 1/10 W, 1%
67	1	R50	Resistor	ERJ8BSFR11V	1206	Panasonic	0.11	Resistor, Chip, 1/2 W, 1%
68	1	R51	Resistor	ERJ8BSFR12V	1206	Panasonic	0.12	Resistor, Chip, 1/2 W, 1%
69	2	R15 R19	Resistor	Std	1206	Std	2.7 K	Resistor, Chip, 1/4 W, 1%
70	2	R12 R46	Resistor	Std	1206	Std	22	Resistor, Chip, 1/4 W, 1%
71	9	R21–23 R25 R27–28 R40–42	Resistor	Std	1206	Std	3.3 M	Resistor, Chip, 1/4 W, 1%
72	1	C41	Electrolytic capacitor	KF470M025C110A	6.3 mm × 11 mm	CapXon	100 µF, 25 V	size:5 mm × 11 mm
73	1	C32	Electrolytic capacitor	OLKJ3552W151MF	18 mm × 35.5 mm	YMIN	150 µF, 450 V	size:18 mm × 35.5 mm
74	4	C13–14 C27 C51	Hybrid Electrolytic capacitor	VHTE1701H271MVCG	10*17	YMIN	270 µF, 50 V	size: SMD10*17, ESR 15 mΩ
75	1	ZD2	Zener	MM3Z16VT1G	SOD323	onsemi	16 V	GENERIC ZENER-DIODE
76	1	ZD1	Zener	MM3Z33VT1G	SOD323	onsemi	33 V	GENERIC ZENER-DIODE

References

- [1] onsemi datasheet for [NCP1680](#), [NCP13994](#), [NCP51530](#), [NCP4306](#), [NCP58921](#), [NCP58922](#), [FDMS4D0N12C](#), [NTMT064N65S3H](#)
- [2] onsemi Design Notes [TND6412](#)

onsemi, Onsemi, and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "onsemi" or its affiliates and/or subsidiaries in the United States and/or other countries. onsemi owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of onsemi's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. onsemi reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and onsemi makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does onsemi assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using onsemi products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by onsemi. "Typical" parameters which may be provided in onsemi data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. onsemi does not convey any license under any of its intellectual property rights nor the rights of others. onsemi products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use onsemi products for any such unintended or unauthorized application, Buyer shall indemnify and hold onsemi and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that onsemi was negligent regarding the design or manufacture of the part. onsemi is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Email Requests to: orderlit@onsemi.com

onsemi Website: www.onsemi.com

TECHNICAL SUPPORT
North American Technical Support:
Voice Mail: 1 800-282-9855 Toll Free USA/Canada
Phone: 011 421 33 790 2910

Europe, Middle East and Africa Technical Support:
Phone: 00421 33 790 2910
For additional information, please contact your local Sales Representative