140 W Two-Switch Combo PFC & QR Flyback for USB PD3.1 EPR Solution

TND6511/D

SPECIFICATION

onsemi's Devices	Applications	Input Voltage	Output Power	Topology	I/O Isolation
1*NCP1945 1*NCP51530BMNTWG 1*NCP4307FASNT1G 1*NCP58921 2*NCP58922 2*NTMT064N65 1*FDMS4D0N12C	PD3.1 adapter for computer, smart phone and other applications	90 Vac to 264 Vac	140 W	CrMPFC+2SW QR Flyback	Isolated

	Output Specification
Output Voltage	5 V, 9 V, 12 V, 15 V, 20 V, 28 V
Max Current	5 A
Min Current	zero

Efficiency	91.86% & 93.34% @ 115 Vac & 230 Vac 28 V/5 A
Protection	OVP, OCP, SCP, OTP
PCBA Size	65 mm x 45 mm x 20 mm

Circuit Description

This reference design describes a 140 W PD3.1 ERP solution using NCP1945 and NCP4307 with CrM PFC pluses 2SW QR flyback power supply for PD3.1 smart phone super charger, NB adaptor and general power supply supporting 140 W with high efficiency and compact profile.

The featured PFC solution uses CrM PFC controller , HF QR Flyback and syn. controller NCP4307 for variable output from 5 V to 28 V to meet PD3.1 EPR specification. GaN NCP58921 (SJ-MOSFET) are used for PFC SW and 2 drive GaN NCP58922 for 2SW QR Flyback.

This reference design provides the complete circuit schematic details, PCB layout, EVM photo, inductor, transformer specification and BOM for 140 W PD3.1 EPR solution, also some key waveforms for reference.

A dual layer PCB is designed for a demonstration although totem pole PFC has more component and complex replacement, also consider easy to test, only 1 simulated PD3.1 output daughter card is used.

No 28 V protocol controller selected, so one simulated PD3.1 daughter card is designed to support wide output by changing NCP431's reference voltage through resistor divider, daughter card interface provides Vo, aux. Vo, feedback FB and PFC ON/OFF interface, so this interface can be compatible with a standard protocol daughter card. Some issues occur while output voltage is changed because of no protocol controller used, also some critical solutions are provided and let's work properly.

Key Features

- AC Input from 90 V to 264 V
- CrM PFC+2SW QR Flyback Topology
- High Frequency Operation with Drive GaN, 50 mΩ for TPPFC and 75 mΩ for Flyback
- Simulated Circuit to Support PD3.1 Multi-output
- Daughter Card Interface is Compatible with 28 V PD3.1 Protocol
- Output Voltage and Current 5 V, 9 V, 12 V, 15 V, 20 V, 28 V and 5 A
- Max Output Power: 140 W
- Low Standby Power: <80 mW in Universal
- AVG Efficiency: 91.42% & 92.27% at 115 Vac&230 Vac and 28 V
- Full Load Efficiency:
  91.86% & 93.34% at 115 Vac & 230 Vac and 28 V 5 A
- Precise Output OVP by Primary Control
- Precise Primary Constant Current Control for Constant
- OCP for Every Output Voltage
- SCP and Open Loop Protection
- 2 layers PCB Used and Name Card Size with Compact Design
- PCBA Size: 65 mm x 45 mm x 20 mm
- Power Density: 39 W/in^3

BOARD PHOTOS

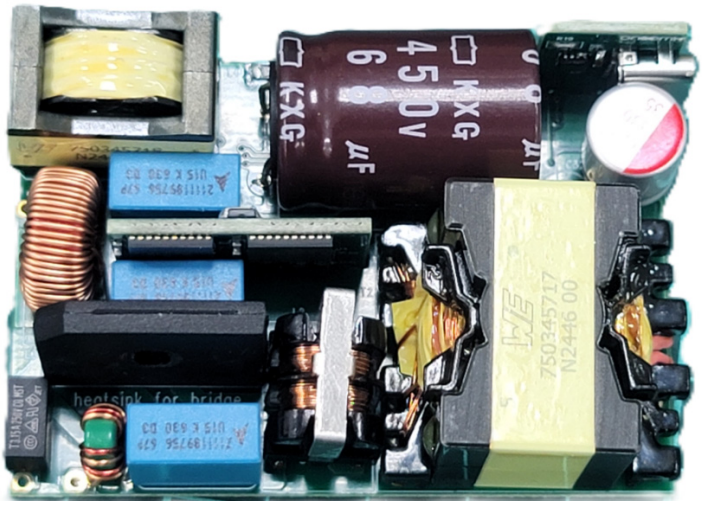


Figure 1. The Front View of 140 W EVM

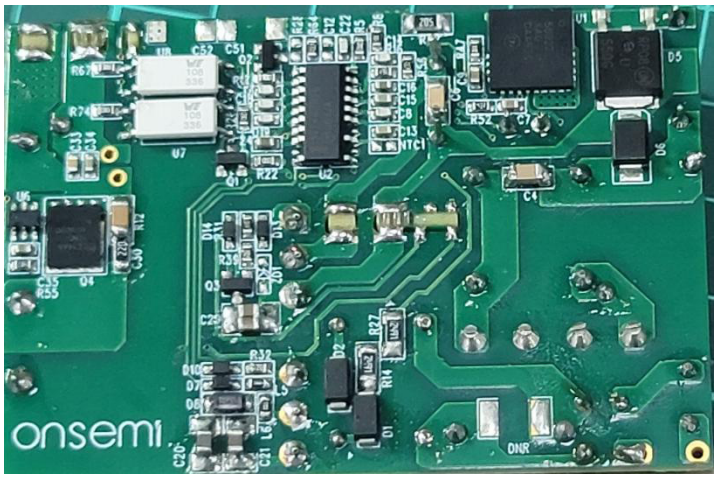


Figure 2. Reverse Side of 140 W EVM

CIRCUIT SCHEMATIC

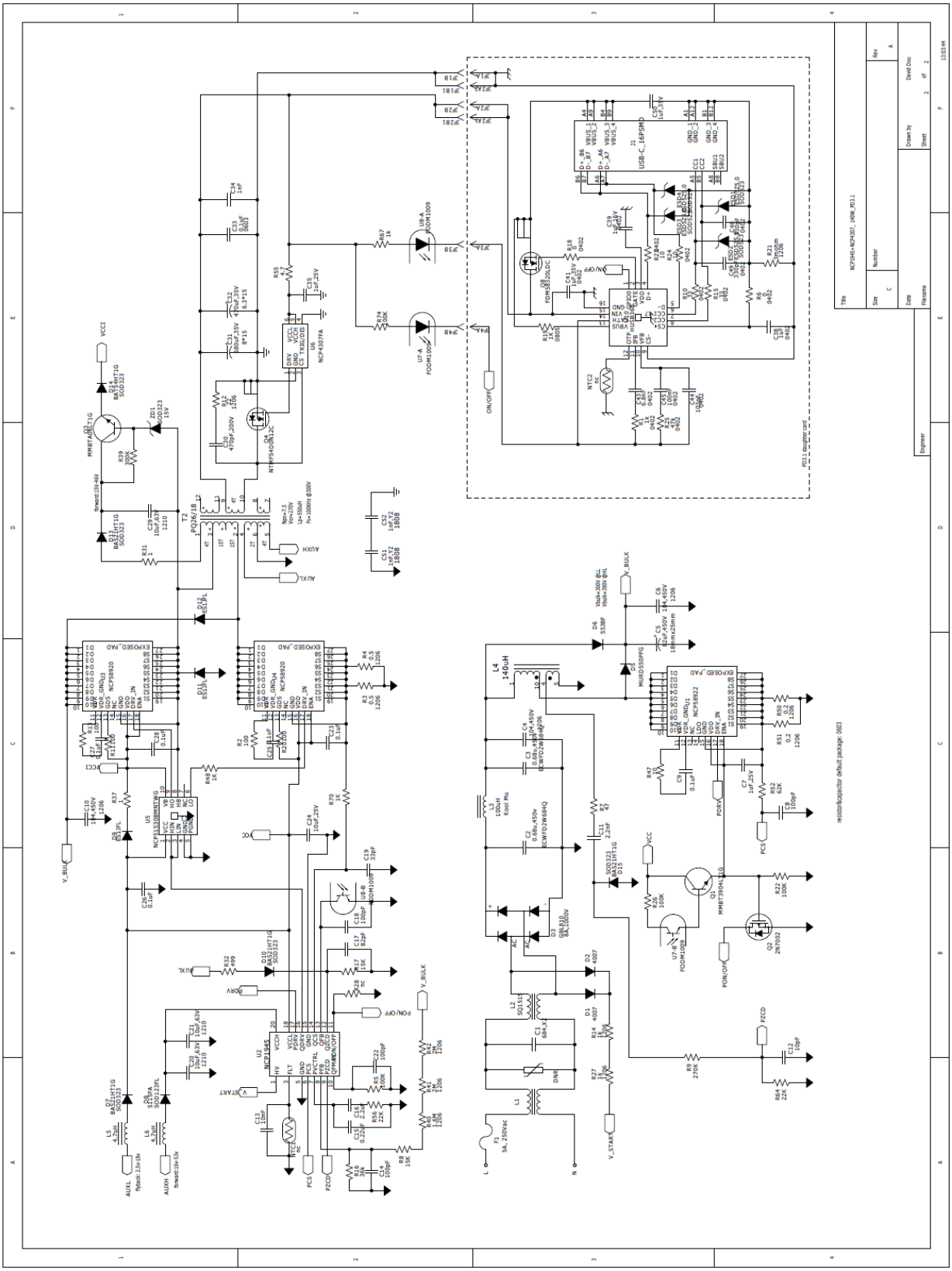


Figure 3. Schematic

PCB LAY OUT

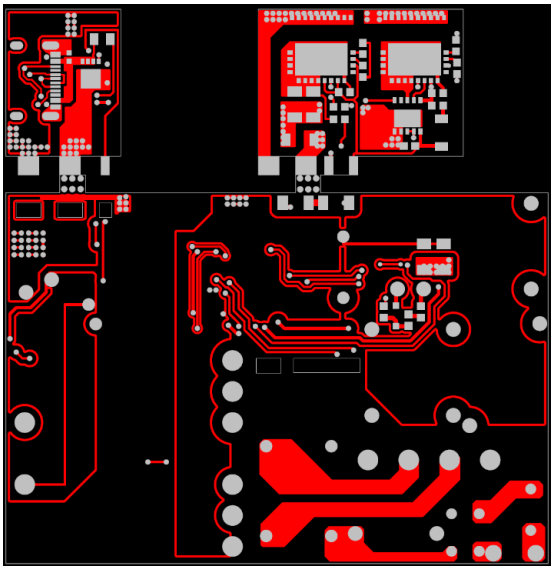


Figure 4. Top View

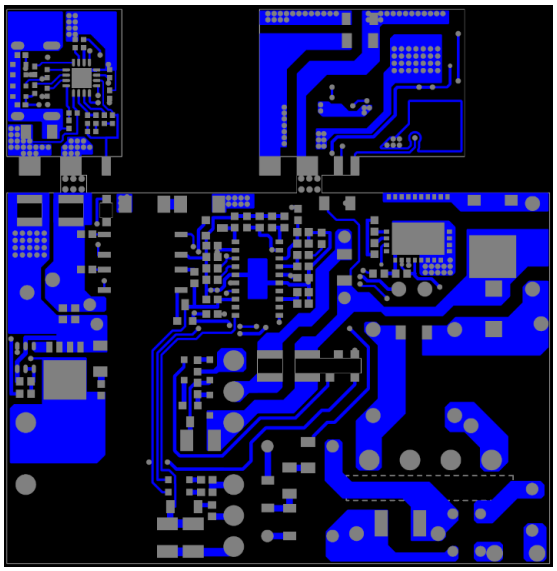


Figure 5. Bottom View

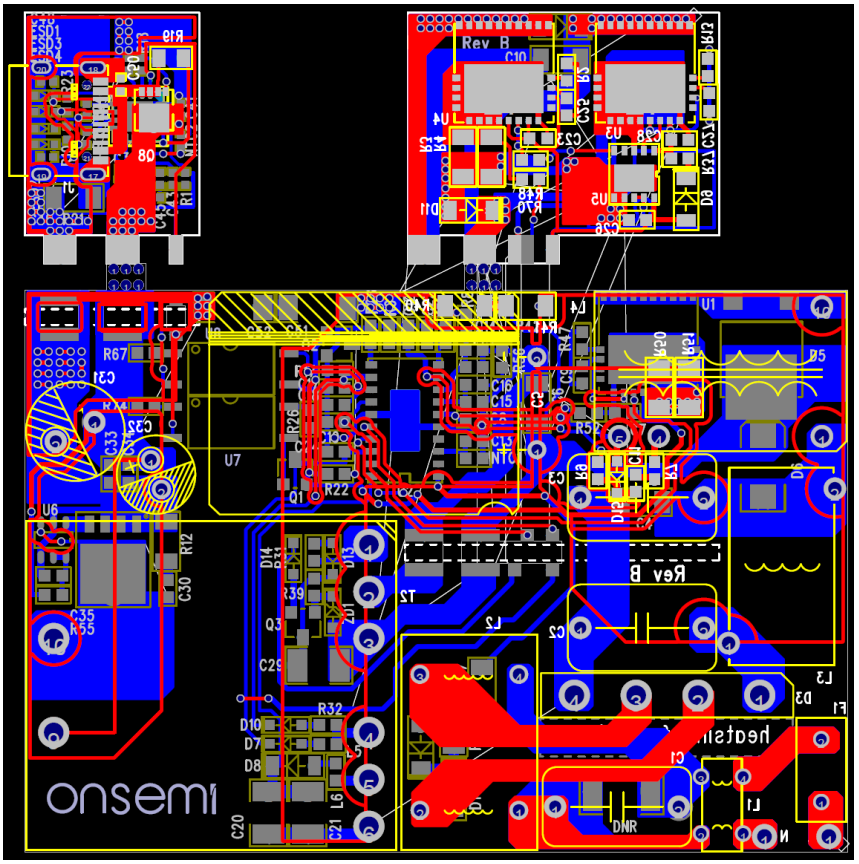


Figure 6. All View

PFC INDUCTOR DESIGNS

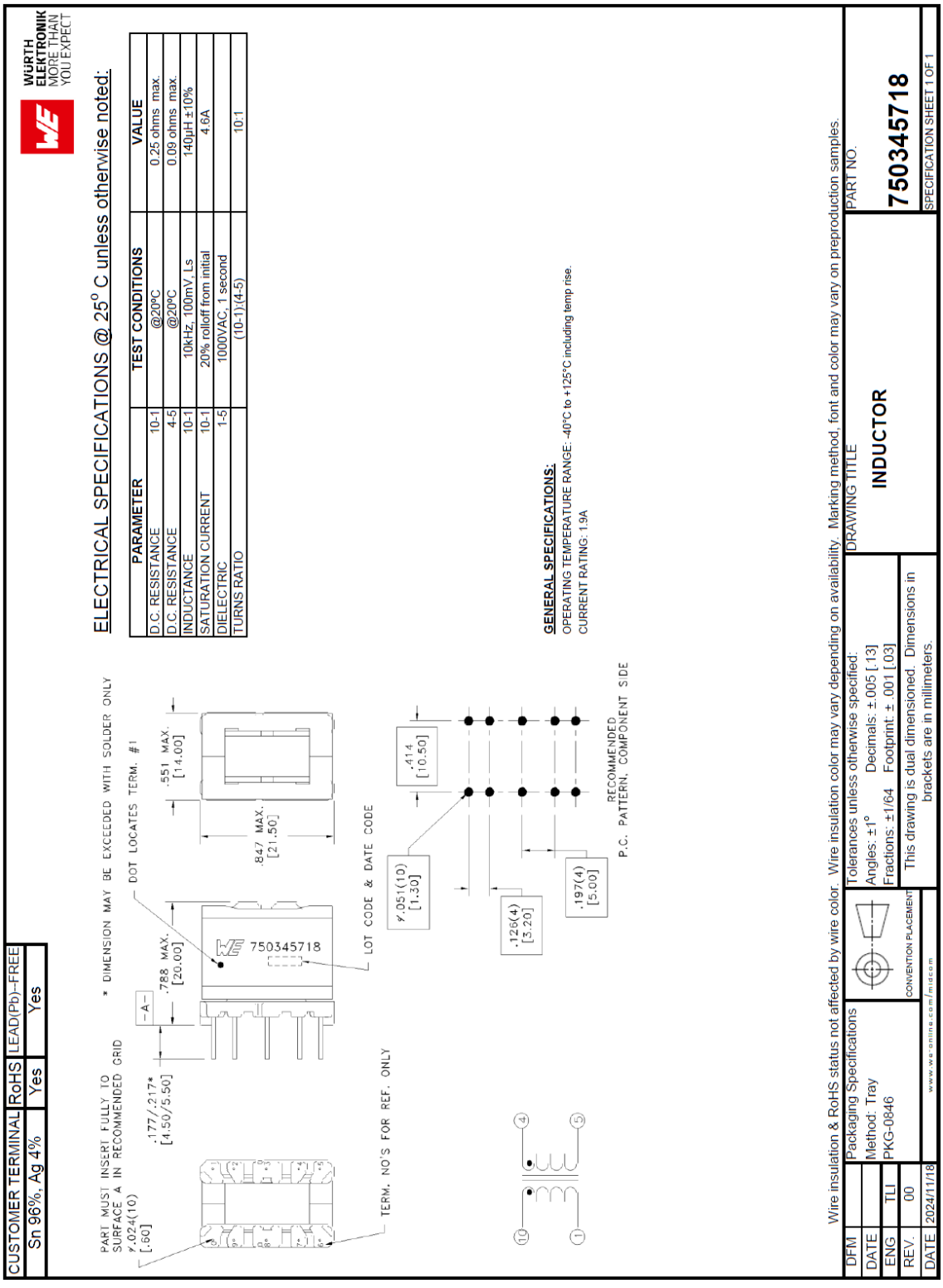


Figure 7. PFC Inductor Specification

PWM TRANSFORMER DESIGNS

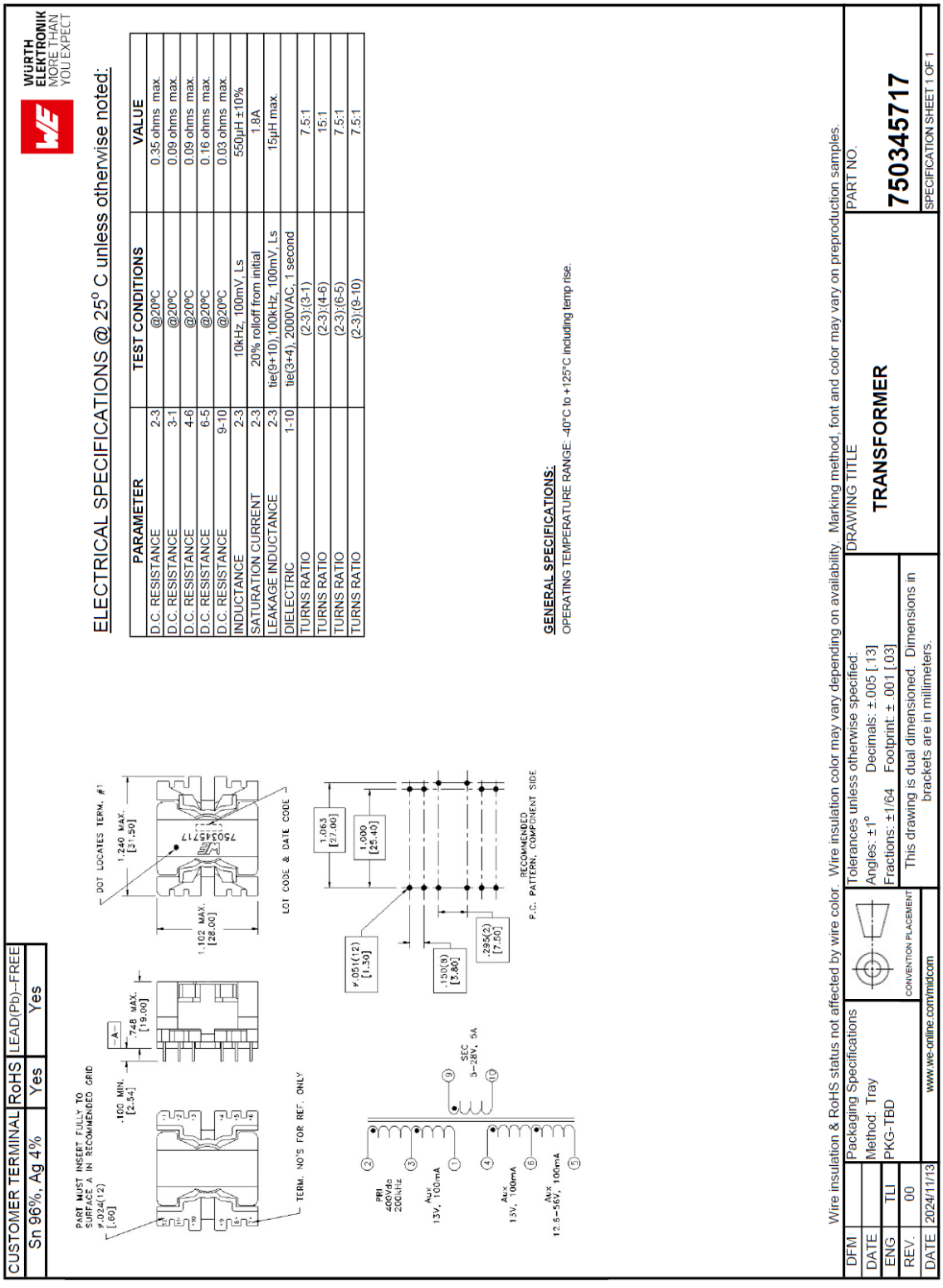


Figure 8. PWM Transformer Specification

Efficiency vs. Load

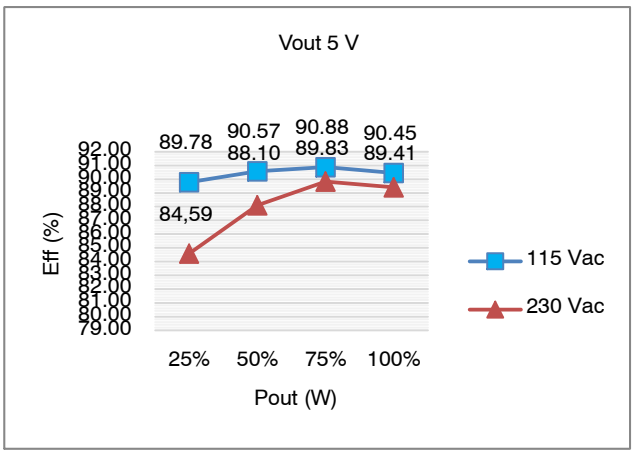


Figure 9. 5 V

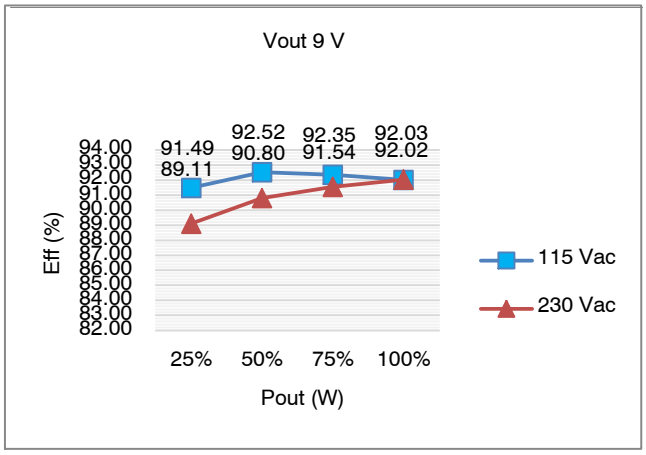


Figure 10. 9 V

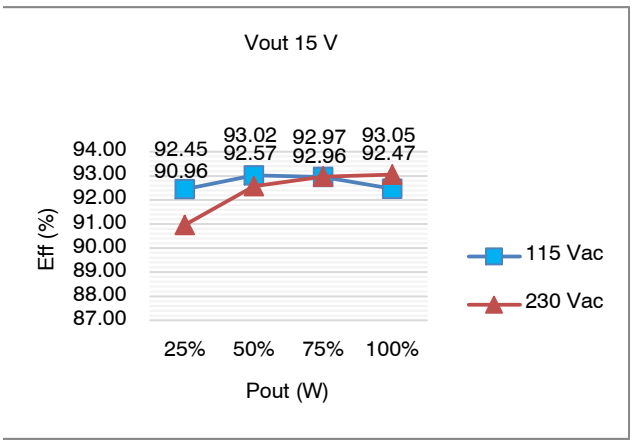


Figure 11. 15 V

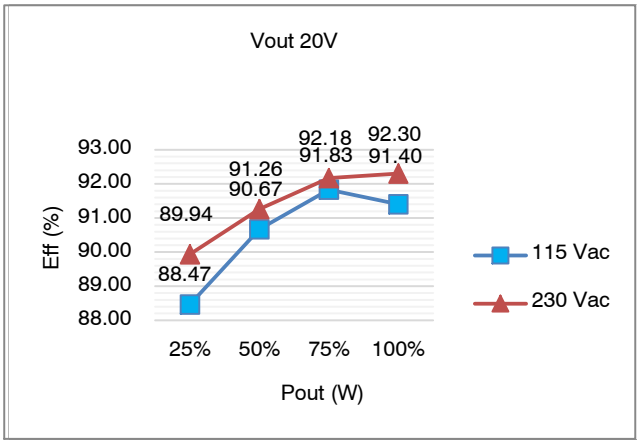


Figure 12. 20 V

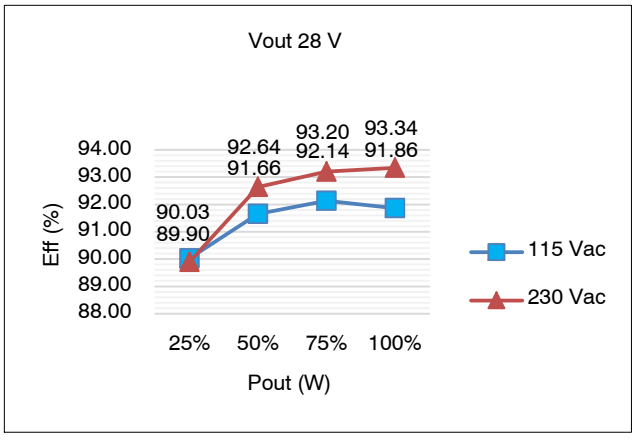


Figure 13. 28 V

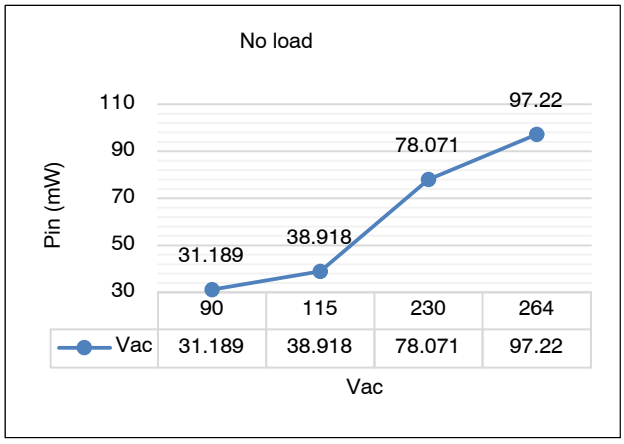


Figure 14. Standby Power

AC Input Waveform

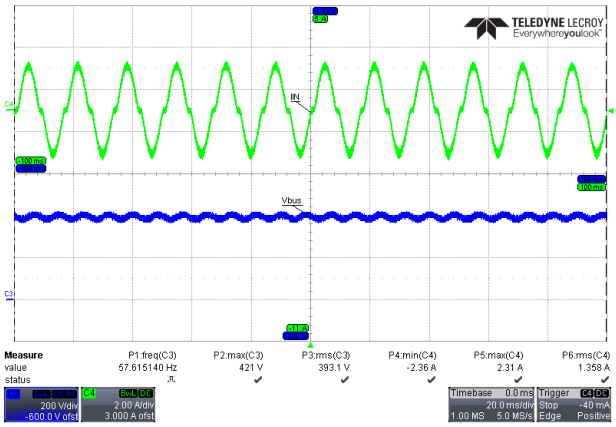


Figure 15. 115 Vac and Full Load (ch3-Vbus, ch4-lin)

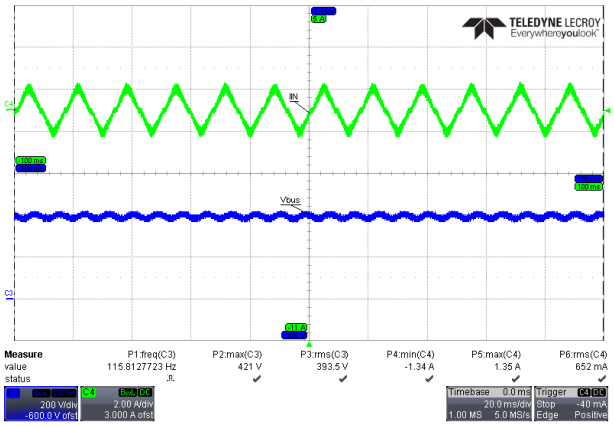


Figure 16. 230 Vac and Full Load (ch3-Vbus, ch4-lin)

Start-up Waveform

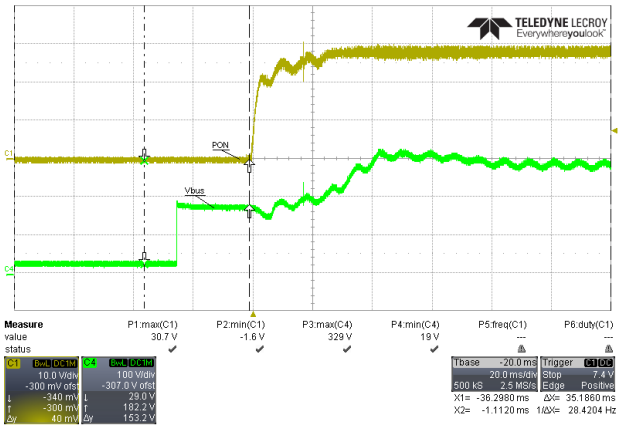


Figure 17. 0 to Full Load Transition at 90 Vac (ch1-Vout, ch4-Vbus)

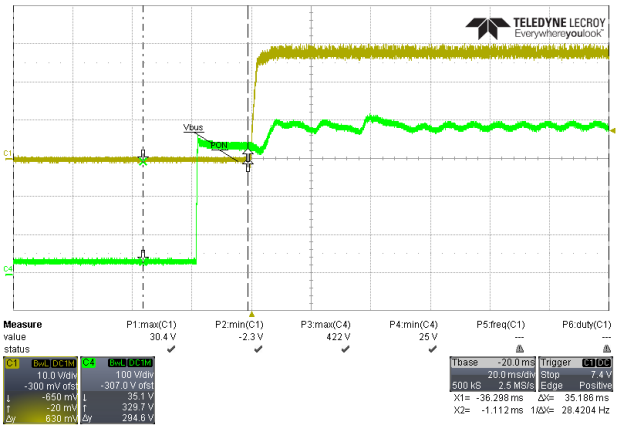


Figure 18. Full Load to 0 Transition at 90 Vac (ch1-Vout, ch4-Vbus)

PFC Skip Mode and Follow Boost Waveform

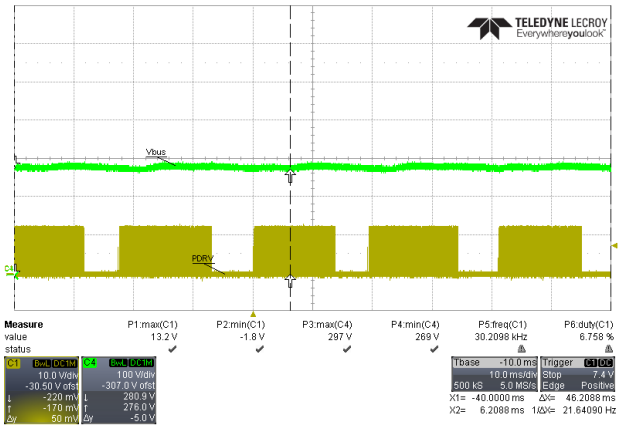


Figure 19. Load 28 V/0.5 A at 115 Vac (ch1-PDRV, ch4-Vbuc)

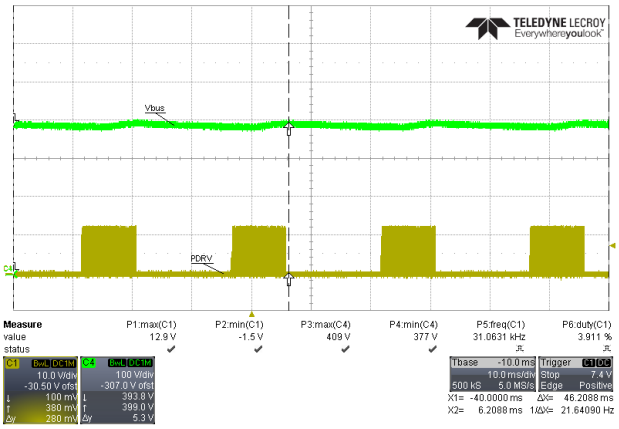


Figure 20. Load 28 V/0.5 A at 230 Vac (ch1-PDRV, ch4-Vbuc)

PWM Operation Waveform

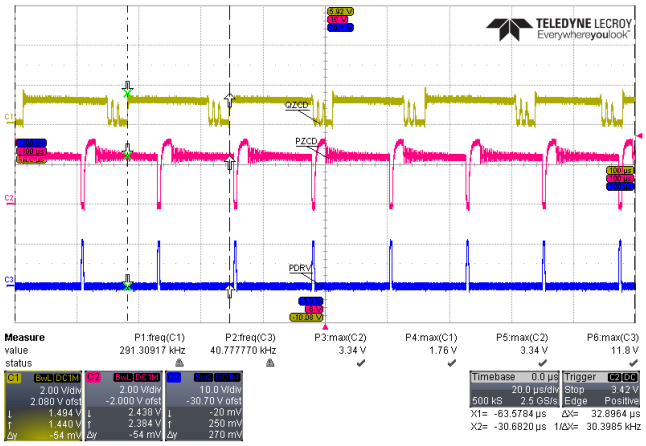


Figure 21. 115 Vac and Full Load (ch1-QZCD, ch2-PZCD, ch3-PDRV)

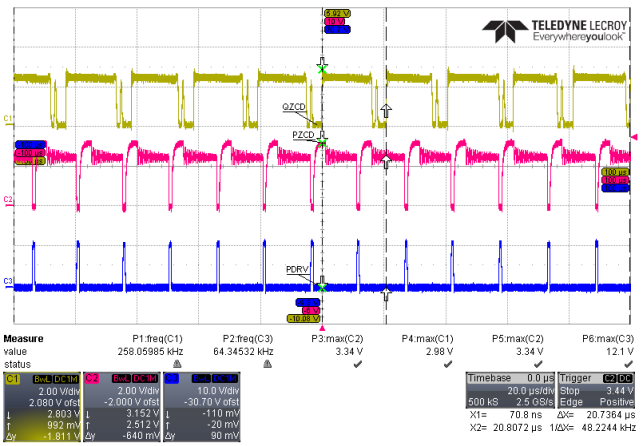


Figure 22. 230 Vac and Full Load (ch1-QZCD, ch2-PZCD, ch3-PDRV)

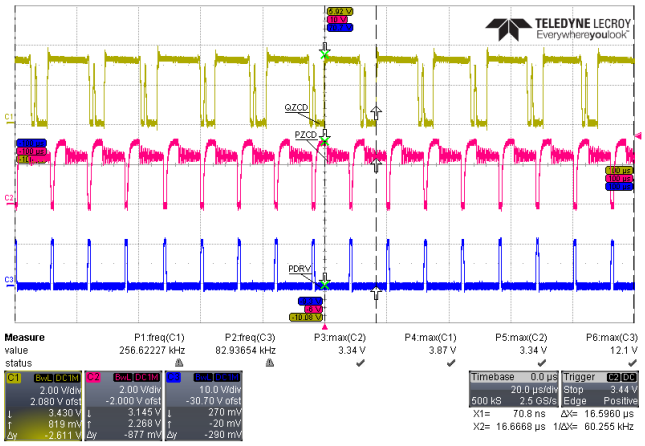


Figure 23. 0 to Full Load Transition at 90 Vac (ch1-QZCD, ch2-PZCD, ch3-PDRV)

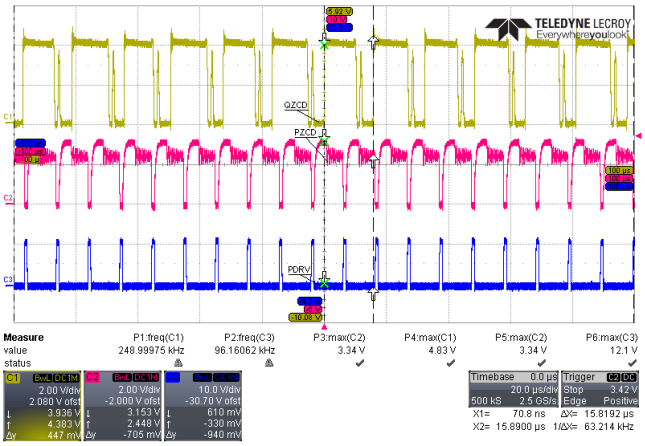


Figure 24. Full Load to 0 Transition at 90 Vac (ch1-QZCD, ch2-PZCD, ch3-PDRV)

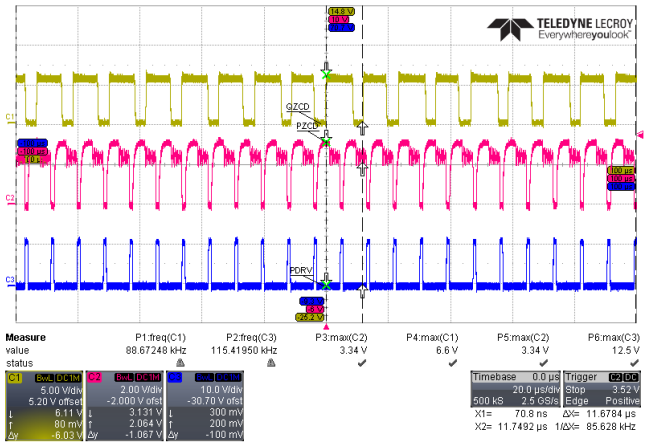


Figure 25. 115 Vac to 230 Vac Transition at Full Load (ch1-QZCD, ch2-PZCD, ch3-PDRV)

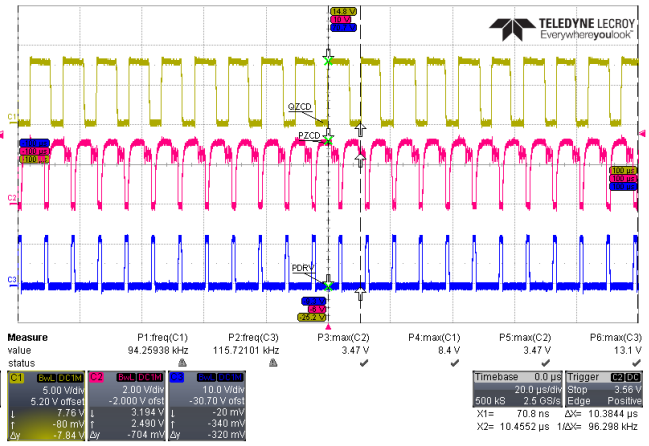


Figure 26. 230 Vac to 115 Vac Transition at Full Load (ch1-QZCD, ch2-PZCD, ch3-PDRV)

SR Waveform

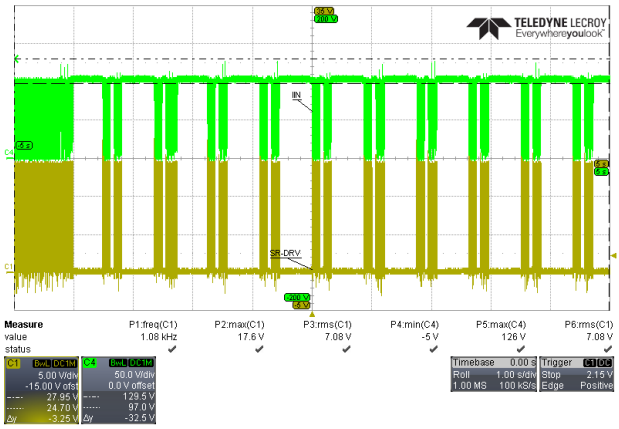


Figure 27. Vout 28 V NCP4307 (SR) (ch1-SR_DRV, ch4-SR_CS)

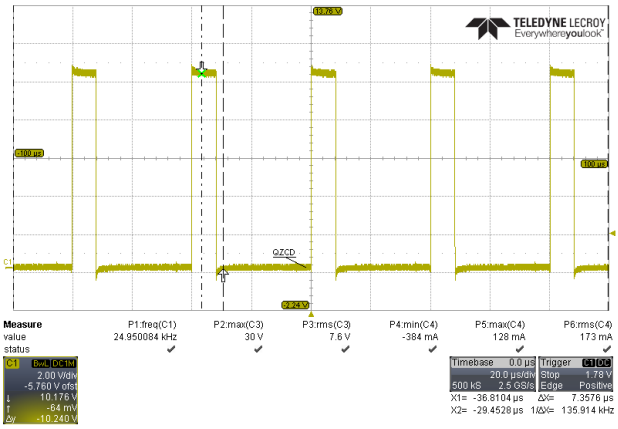
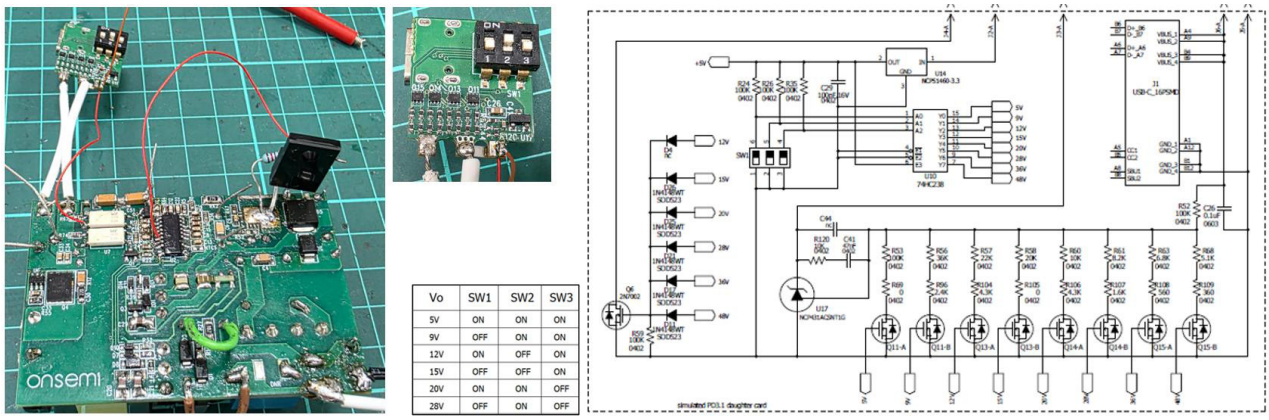


Figure 28. Vout 28 V NCP4307 (SR) (ch1-SR_DRV)

DIP SW to Simulate PD Controller

No PD3.1 controller to support 28 V in current market, so a discrete circuit to simulate PD3.1 and support 5 V, 9 V, 12 V, 15 V 20 V and 28 V by 3 DIP SW with 6 combination as following.



Vo	SW1	SW2	SW3
5V	ON	ON	ON
9V	OFF	ON	ON
12V	ON	OFF	ON
15V	OFF	OFF	ON
20V	ON	ON	OFF
28V	OFF	ON	OFF

Figure 29. Simulate PD Controller

Table 1. BOM

Item	Qty	Reference	Part Name	Manufacturer		Description
1	1	C1	C603, 684, X2			X2 capacitor, Safety standard approved, 10%
2	1	C5	SECAP\140\300, 82 μF, 450 V			Size:18 mm x 30 mm
3	1	C11	C603, 1.5 nF	WALSIN	0603B222K500CTSOM	Capacitor, Ceramic, 50 V, 10%
4	1	C15	C603, 0.22 μF	WALSIN	0603B224K250CTXOM	Capacitor, Ceramic, 25 V, 10%
5	1	C16	C603, 2.2 μF	WALSIN	0603B225K160CTXOM	Capacitor, Ceramic, 16 V, 10%
6	1	C17	C603, 82 pF	WALSIN	0603N820J500CTSOM	Capacitor, Ceramic, 50 V, 10%
7	1	C19	C603, 33 pF	WALSIN	0603N330J500CTSOM	Capacitor, Ceramic, 50 V, 5%
8	1	C24	C603, 10 μF, 25 V	WALSIN	0603X106M250CTXOM (20%)	Capacitor, Ceramic, 25 V, 10%
9	1	C29	C603, 4.7 μF, 63 V	WALSIN	1210B475K101CTMOM	Capacitor, Ceramic, 63 V, 10%
10	1	C30	C603, 470 pF, 200 V	WALSIN	0603N471J201CTSOM	Capacitor, Ceramic, SMD, 10%
11	1	C31	SECAP\140\300, 680 μF, 35 V			size:6.3x15, ESR 11 mΩ
12	1	C32	SECAP\140\300, 470 μF, 35 V			size:6.3x15, ESR 11 mΩ
13	1	C34	C603, 1 nF	WALSIN	0603B102K500CTSOM	Capacitor, Ceramic, 50 V, 10%
14	1	C38	C603, 1 μF	WALSIN	0603B105K500CTXOM	Capacitor, Ceramic, 50 V, 10%
15	1	C39	C603, 1 μF, 16 V	WALSIN	0603B105K500CTXOM	Capacitor, Ceramic, 50 V, 10%
16	2	C12 C44	C603, nc	WALSIN	(C12) 0603N100J500CTSOM (C44) 0603B104K500CTXOM	Capacitor, Ceramic, 50 V, 10%
17	3	C13 C43 C45	C603, 10 nF	WALSIN	(C13) 0603B103K500CTSOM (C43) 0603N682J500CTSOM (C45) 0603B104K500CTXOM	Capacitor, Ceramic, 50 V, 10%
18	2	C2 C3	C603, 0.68 u, 450 v	WALSIN	1812B684K451CTMOM	Film capacitor
19	2	C20 C21	C603, 10 μF, 63 V	WALSIN	(63V) 1210B106K630CTMOM (50V) 1210B106K500CTMOM	Capacitor, Ceramic, 63 V, 10%
20	3	C4 C6 C10	C603, 104, 450 V	WALSIN	1206B104J451CTGOM	Capacitor, Ceramic, SMD, 5%
21	2	C41 C50	C603, 1 μF, 35 V	WALSIN	0603B105K500CTXOM	Capacitor, Ceramic, 50 V, 10%
22	2	C48 C49	C603, 330 pF	WALSIN	0603N331J500CTSOM	Capacitor, Ceramic, 50 V, 10%
23	2	C51 C52	C603, 1 nF, Y2			HV Ceramic Capacitor,safety standard approved, 10%
24	2	C7 C35	C603, 1 μF, 25 V	WALSIN	0603B105K250CTXOM	Capacitor, Ceramic, 25 V, 10%
25	4	C8 C14 C18 C22	C603, 100 pF	WALSIN	0603N101J500CTSOM Add(C18)WR06X4992FTL20OM	Capacitor, Ceramic, 50 V, 10%
26	7	C9 C23 C25 C26 C27 C28 C33	C603, 0.1 μF	WALSIN	0603B104K500CTXOM	Capacitor, Ceramic, 50 V, 10%
27	1	D3	D-BRIDGE_HD04, 8 A, 1000 V			Bridge Rectifier, 1000 V, 8 A
28	1	D5	MURD550, 5 A, 520 V			Ultrafast Rectifier, 5 A, 520 V
29	1	D6	DIODE, 5 A, 600 V			General Rectifier
30	1	D8	D_RECT_SOD323, 1 A, 150 V			Schotty diode, SMD
31	1	D9	D_RECT_SMA, 1 A, 600 V			General Rectifier, 1 A, 600 V
32	1	D14	D_RECT_SOD323, 0.2 A, 30 V			Schotty diode, SMD
33	2	D1 D2	D_RECT_SMA, 0.8 A, 600 V			General Rectifier, 0.8 A, 600 V
34	2	D11 D12	DIODE, 1 A, 600 V			Ultrafast rectifier
35	4	D7 D10 D13 D15	D_RECT_SOD323, 0.2 A, 250 V			Switching diode, SMD
36	1	DNR	DNR, 10D471K			Varistor, 10D471K
37	4	ESD1 ESD2 ESD3 ESD4	ZENER-DIODE			GENERIC ZENER-DIODE
38	1	F1	FUSE, 5 A, 250 Vac			Micro Fuse, 1.6 A/250 V

Table 1. BOM (continued)

Item	Qty	Reference	Part Name	Manufacturer		Description
39	1	J1	USB-C_16PSMD	WURTH ELEKTRONIK	WE 632722200211	Type C connector, SMT
40	1	L1	FILTER_L1, 30 μH			T type, 8*4*3 NiZn core
41	1	L2	FILTER_L2, 18 mH			CM Filter
42	1	L3	PMP4301_L3, 100 μH			Toroidal Line Choke, 15.8x8.5, 2.5 A
43	1	L4	EQ20_QRPFC, 140 μH	WURTH ELEKTRONIK	WE 750345718	RM8, Ferroxcube 3C95 core, 6Pin Bobbin
44	2	L5−6	PMP4301_L3, 4.7 μH			
45	2	NTC1−2	NTC, nc			
46	1	Q1	MMBT3904LT1,0.5A, 80 V	**onsemi**		General NPN Transistor, SMD
47	1	Q2	2N7002, 0.2 A, 60 V	**onsemi**		NMOSFET, 0.2 A, 60 V
48	1	Q3	MMBT3904LT1, 0.5 A, 80 V	**onsemi**		GENERAL PURPOSE NPN SILICON TRANSISTOR
49	1	Q4	NMOS_5X6, 120 V, 4 mΩ	**onsemi**		MOSFET, NChan, 120 V
50	1	Q8	TR-CSD16407Q5, 40 V, 1.5 mΩ	**onsemi**		MOSFET, NChan, 1.5 mΩ @ 4.5 V
51	1	R7	R603, 47	WALSIN	WR06X47R0FTL20OM	Resistor, Chip, 1/10W, 1%
52	1	R8	R603, 15 k	WALSIN	WR06X1502FTL20OM	Resistor, Chip, 1/10W, 1%
53	1	R9	R603, 270 k	WALSIN	WR06X2703FTL20OM	Resistor, Chip, 1/10W, 1%
54	1	R12	R0805, 22	WALSIN	WF12P22R0FTL20OM	Resistor, Chip, 1/4W, 1%
55	1	R16	R603, 36 k	WALSIN	WR06X3602FTL20OM	Resistor, Chip, 1/10W, 1%
56	1	R17	R603,150 k	WALSIN	WR06X1503FTL20OM	Resistor, Chip, 1/10W, 1%
57	1	R21	R0805, 5 mΩ	WALSIN	WW12MR003FTL20OM	Resistor, Chip, 1/2W, 1%
58	1	R28	R603, nc			Resistor, Chip, 1/10W, 1%
59	1	R32	R603, 620	WALSIN	WR06X4990FTL20OM	Resistor, Chip, 1/10W, 1%
60	1	R39	R603, 300 k	WALSIN	WR06X3003FTL20OM	Resistor, Chip, 1/10W, 1%
61	1	R40	R0805, 1.6 M	WALSIN	WF12P1604FTL20OM	Resistor, Chip, 1/4W, 1%
62	1	R47	R603, 10	WALSIN	WR06X10R0FTL20OM	Resistor, Chip, 1/10W, 1%
63	1	R52	R603, 4.7 k	WALSIN	WR06X472 JTL20OM	Resistor, Chip, 1/10W, 5%
64	1	R55	R603, 4.7	WALSIN	WR06W4R70FTL20OM	Resistor, Chip, 1/10W, 1%
65	1	R56	R603, 22 k	WALSIN	WR06X2202FTL20OM	Resistor, Chip, 1/8W, 1%
66	1	R64	R603, 22 k	WALSIN	WR06X2202FTL20OM	Resistor, Chip, 1/10W, 1%
67	1	R67	R603, 2 k	WALSIN	WR06X2001FTL20OM	Resistor, Chip, 1/10W, 1%
68	2	R1 R25	R603, 10 k	WALSIN	WR04X1001FTL20OM	Resistor, Chip, 1/16W, 1%
69	4	R10 R15 R23−24	R603, 10	WALSIN	WR04X33R0FTL20OM	Resistor, Chip, 1/16W, 1%
70	2	R14 R27	R0805, 2.7 k	WALSIN	WR12X1001FTL20OM	Resistor, Chip, 1/4W, 1%
71	3	R19 R48 R70	R603, 1 k	WALSIN	WR06X1001FTL20OM	Resistor, Chip, 1/10W, 1%
72	2	R2 R13	R603, 100	WALSIN	WR06X1000FTL20OM	Resistor, Chip, 1/10W, 1%
73	2	R3−4	R0805, 0.62	WALSIN	WW12WR500FTL_GN20OM	Resistor, Chip, 1/2W, 1%
74	2	R31 R37	R603, 1	WALSIN	WR06W1R00FTL20OM	Resistor, Chip, 1/10W, 1%
75	2	R41 R42	R0805, 2 M	WALSIN	WR12W2004FTL20OM	Resistor, Chip, 1/4W, 1%
76	4	R5 R22 R26 R74	R603, 100 k	WALSIN	WR06X1003FTL20OM	Resistor, Chip, 1/10W, 1%
77	2	R50 R51	R0805, 0.18	WALSIN	WW12WR200FTL_GN20OM	Resistor, Chip, 1/2W, 1%
78	2	R6 R18	R603, 1 k	WALSIN	WR04X000 PTL20OM	Resistor, Chip, 1/16W, 1%

Table 1. BOM (continued)

Item	Qty	Reference	Part Name	Manufacturer		Description
79	1	T2	PQ32/20_DUAL-SW_140W,PQ26/18	WURTH ELEKTRONIK	WE 750345717	Ferroxcube 3C95, 12Pin Bobbin
80	1	U1	NCP58922	**onsemi**		
81	1	U2	NCP1945	**onsemi**		
82	1	U5	NCP51530-DFN	**onsemi**		
83	1	U6	NCP4307	**onsemi**		
84	1	U10	HUSB362			PD protocol controller
85	2	U3−4	NCP58920	**onsemi**		
86	2	U7 U8	OPTICAL-A	WURTH ELEKTRONIK	1,401E+11	optical coupler, standard SOP package
87	1	ZD1	ZENER-DIODE, 13 V	**onsemi**		GENERIC ZENER-DIODE

References

[1] **onsemi** datasheet for NCP1945, NCP51530, NCP4307, NCP58921, NCP58922

REVISION HISTORY

Revision	Description of Changes	Date
0	Initial document release.	4/9/2026

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