240 W USB PD3.1 EPR - CrM Totempole PFC and 2 Switch Flyback Solution

TND6458/D

onsemi's Devices	Applications	Input Voltage	Output Power	Topology	I/O Isolation
NCP1680 NCP1345Q01 3*NCP51530BMNTWG 1*NCP4307FASNT1G 2*NCP58921 2*NCP58922 2*NTMT064N65S3H 1*FDMS4D0N12C	PD3.1 adapter for computer, smart phone and other applications	90 Vac to 264 VAc	240 W	TPPFC + 2sw QR Flyback	Isolated

	Output Specification
Output Voltage	5 V, 9 V, 12 V, 15 V, 20 V, 28 V, 36 V, 48 V
Max Current	5 A
Min Current	zero

Efficiency	95.12% & 96.17% @ 115 Vac & 230 Vac and 48 V 5 A
Protection	OVP, OCP, SCP, OTP
PCBA	98 mm × 51 mm × 21.5 mm

Circuit Description

This reference design describes a 240 W PD3.1 ERP solution using NCP1680, NCP1345 and NCP4307 with TPPFC pluses 2sw QR flyback power supply for PD3.1 smart phone super charger, NB adaptor 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 QR Flyback controller NCP1345 and syn. controller NCP4307 for variable output from 5 V to 48 V to meet PD3.1 EPR specification. 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 2sw QR Flyback.

This reference design provides the complete circuit schematic details, PCB layout, EVM photo, inductor, transformer specification and BOM for 240 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.

PFC starts to operate above 15 V output, PFC's Vcc is supplied by flyback and controlled by secondary circuit, two forward auxiliary winding are designed to supply Vcc to PWM/PFC and high side GaN because of large output voltage variable ratio, also a flyback auxiliary winding and output are designed to supply voltage to syn. controller, feedback optical−coupler and daughter card in parallel to meet controller's voltage rating and reduce the power loss.

Another special design is to get a negative pulse which is corresponding to PWM's skip status from PWM gate drive and connected to PFCOK pin of PFC controller to force PFC into skip mode, in this skip mode PFC works at forced skip mode and Vbulk voltage is changed between 94% of rating output and rating output, so PFC's power loss can be reduced in PWM skip mode.

No 48 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 on page 22 and let's work properly.

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Key Features

- AC input from 90 V to 264 V
- TPPFC + 2SW QR Flyback topology
- High Frequency operation with GaN, 50 mΩ for TPPFC and 75 mΩ for flyback
- Simulated circuit to support PD3.1 multi−output
- Daughter card interface is compatible with 48 V PD3.1 protocol
- Output voltage and current 5 V, 9 V, 12 V, 15 V, 20 V, 28 V, 36 V, 48 V and 5 A
- Max Output power: 240 W
- Low standby power: <120 mW in universal
- Ripple&Noise: <150 mV @5 V−12 V and <230 mV @15 V−48 V
- AVG efficiency: 94.75% & 95.43% at 115 Vac & 230 Vac and 48 V
- Full load efficiency: 95.12% & 96.17% at 115 Vac & 230 Vac and 48 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: 89 mm × 51 mm × 21.5 mm
- Power Density: 40 W/in^3

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

CIRCUIT SCHEMATIC (TPPFC PORTION)

Figure 4. Schematic for TPPFC Portion

CIRCUIT SCHEMATIC (PWM AND SIMULATED PD3.1 DAUGHTER CARD PORTION)

Figure 5. Schematic for PWM and Simulated PD3.1 Daughter Card Portion

PCB LAYOUT

Figure 6. Top View

Figure 7. Bottom View

PFC INDUCTORS DESIGNS

1. Core and Bobbin

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

2. Electrical diagram

WD1=Primary, 30T, 50*0.1mm Litz

WD2=Auxiliary, 3T, 0.17mm

3. Electrical specification

Electrical Strength	Don't test	
Primary Inductance	Pins 1-5, all other windings open, measured at 10 kHz, 1V	140uH+/-10%

4. Transformer building construction diagram

Figure 8. PFC Inductor Specification

PWM TRANSFORMER DESIGNS

Figure 9. PWM Transformer Specification

AVG. Efficiency and 10% Load Efficiency

Figure 10. Avg. Efficiency

Figure 11. 10% Load Efficiency

Standby Power and PF

Figure 12. Standby Power

Figure 13. PF

Very Light Load Efficiency at 5 V and 0.25 W Efficiency

Figure 14. Very Light Load Efficiency at 5 V

Figure 15. 0.25 W Load Efficiency

Efficiency vs. Load

Figure 16. 5 V

Figure 17. 9 V

Figure 18. 12 V

Figure 19. 15 V

Figure 20. 20 V

Figure 21. 28 V

Figure 22. 36 V

Figure 23. 48 V

PFC Waveform at 90 Vac and Full Load

Figure 24. Vac and Full Load
(ch1−Vin, ch2−Iin, ch3−fast leg SW, ch4−Vbulk)

Figure 25. 90 Vac and Full Load
(ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)

Load Transition

Figure 26. 0 to Full Load Transition at 90 Vac
(ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)

Figure 27. Full Load to 0 Transition at 90 Vac
(ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)

Line Transition

Figure 28. 115 Vac to 230 Vac Transition at Full Load
(ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)

Figure 29. 230 Vac to 115 Vac Transition at Full Load (ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)

PWM Startup Waveform

Figure 30. Power On at 115 Vac and 5 V 0 A
(ch1−Vcc, ch2−Vds−sec, ch3−Vo, ch4−Vdrv)

Figure 31. Power On at 115 Vac and 5 V 0 A, Zoom in
(ch1−Vcc, ch2−Vds−sec, ch3−Vo, ch4−Vdrv)

Figure 32. Power On at 115 Vac and 5 V 3 A
(ch1−Vds−ls, ch2−Vdrv, ch3−Vo, ch4−Vds−hs)

Figure 33. Power On at 115 Vac and 5 V 3 A, Zoom in
(ch1−Vds−ls, ch2−Vdrv, ch3−Vo, ch4−Vds−hs)

PWM Skip Waveform

Figure 34. 115 Vac and 5 V & 0.2 A
(ch1−Vds−hs, ch2−Vds−sec, ch3−Vsyn−drv,
ch4−Vds−ls)

Figure 35. 115 Vac and 48 V & 0.05 A
(ch1−Vds−hs, ch2−Vds−sec, ch3−Vsyn−drv,
ch4−Vds−ls)

PFC & PWM Skip Waveform

Figure 36. Waveform at 115 Vac and 20 V 0 A
(ch1−Vbulk, ch2−Vpfcfastleg, ch3−Vo, ch4−Vds−sec)

Figure 37. Waveform at 115 Vac and 48 V 0 A
(ch1−Vbulk, ch2−Vpfcfastleg, ch3−Vo, ch4−Vds−sec)

PWM Waveform at No Load and Full Load

Figure 38. 115 V and 5 V 0 A
(Ch2−Vds−Is, ch3−Vds_Is, ch4−Vsyn−drv)

Figure 39. 115 Vac and 5 V 5 A
(Ch2−Vds−Is, ch3−Vds_Is, ch4−Vsyn−drv)

Figure 40. 115 V and 20 V 0 A
(Ch2−Vds−Is, ch3−Vds_Is, ch4−Vsyn−drv)

Figure 41. 115 Vac and 20 V 5 A
(Ch2−Vds−Is, ch3−Vds_Is, ch4−Vsyn−drv)

Figure 42. 115 V and 48 V 0 A
(Ch2−Vds−Is, ch3−Vds_Is, ch4−Vsyn−drv)

Figure 43. 115 Vac and 48 V 5 A
(Ch2−Vds−Is, ch3−Vds_Is, ch4−Vsyn−drv)

Output Voltage Transition from 5 V to High Voltage

Figure 44. Voltage Transition from 5 V to 20 V at 0.2 A
(ch1−Vccpwm, ch2−Vds−sec, ch3−Vc58, ch4−Vo)

Figure 45. Voltage Transition from 9 V to 28 V at 0.2 A
(ch1−Vcc−pwm, ch2−Vds−sec, ch3−Vc58, ch4−Vo)

Output Voltage Transition from High Voltage to Low Voltage

Figure 46. Voltage Transition from 20 V to 5 V at 0.2 A
(ch1−Vccpwm, ch2−Vds−sec, ch3−Vc58, ch4−Vo)

Figure 47. Voltage Transition from 28 V to 9 V at 0.2 A
(ch1−Vcc−pwm, ch2−Vds−sec, ch3−Vc58, ch4−Vo)

Output Ripple at 5 A Load

Figure 48. 90 Vac and 5 V (ch3−Vo_ripple)

Figure 49. 90 Vac and 9 V (ch3−Vo_ripple)

Figure 50. 90 Vac and 12 V (ch3−Vo_ripple)

Figure 51. 90 Vac and 15 V (ch3−Vo_ripple)

Figure 52. 90 Vac and 20 V (ch3−Vo_ripple)

Figure 53. 90 Vac and 28 V (ch3−Vo_ripple)

Figure 54. 90 Vac and 36 V (ch3−Vo_ripple)

Figure 55. 90 Vac and 48 V (ch3−Vo_ripple)

Secondary Stress on FET

Figure 56. Power On at 5 V 0.6 A
(ch3−Vo, ch4−Vds−sec)

Figure 57. Operation at 48 V 0.5 A
(ch3−Vo, ch4−Vds−sec)

OCP

Figure 58. 2 A to 6 A Transition at 115 Vac and 5 V
(ch2−Vcs−pri, ch3−Vo, ch4−Vds−sec)

Figure 59. 2 A to 6 A Transition at 115 Vac and 15 V
(ch2−Vcs−pri, ch3−Vo, ch4−Vds−sec)

Thermal Camera Image (Tested after 30 min Operation)

Figure 60. 90 Vac & 48 V 5 A, Front Side

Figure 61. 90 Vac & 48 V 5 A, Reverse Side

Figure 62. 115 Vac & 48 V 5 A, Front Side

Figure 63. 115 Vac & 48 V 5 A, Reverse Side

Figure 64. 230 Vac & 48 V 5 A, Front Side

Figure 65. 230 Vac & 48 V 5 A, Reverse Side

Figure 66. 264 Vac & 48 V 5 A, Front Side

Figure 67. 264 Vac & 48 V 5 A, Reverse Side

Table 1. BOM

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
1	1	Q6	NMOSFET	2N7002	SOT23	**onsemi**	0.2 A, 60 V	NMOSFET, 0.2 A, 60 V
2	1	U10	3−8 line de-code	MC74HC238ADTR2G	TSSOP16	**onsemi**		3−LINE TO 8−LINE DE-CODER\DEMULTIPLEXER
3	11	C3 C6−8 C15−16 C19−20 C26 C40 C45	Ceramic Capacitor	/885012206095	603	Wurth	0.1 μF	Capacitor, Ceramic, 50 V, 10%
4	2	C31 C37	Ceramic Capacitor	C3225X7T2W224K	1210	TDK	0.22 μF, 450 V	Capacitor, Ceramic, Chip, 10%
5	1	C25	X2 Capacitor	/890324024005	THT, 15 mm, 15 mm × 10 mm × 15 mm	Wurth	0.47 μF, 275 VAC	X2 capacitor, Safety standard approved, 10%
6	2	C1 C5	X2 Capacitor	X2 684K310V	THT, 10 mm, 12.5 mm × 8 mm × 20 mm	JURCC	0.68 μF, 310 VAC	X2 capacitor, Safety standard approved, 10%
7	1	C29	Ceramic Capacitor	/885012205037	402	Wurth	100 nF, 16 V	Capacitor, Ceramic, 16 V, 10%
8	6	C9 C35−36 C42−43 C70	Ceramic Capacitor	/885012206077	603	Wurth	100 pF	Capacitor, Ceramic, 50 V, 10%
9	2	C60 C64	Ceramic Capacitor	/885012206089	603	Wurth	10 nF	Capacitor, Ceramic, 50 V, 10%
10	2	C11 C46	Ceramic Capacitor	GRM188R61E106KA73D	603	Murata	10 μF, 25 V	Capacitor, Ceramic, 25 V, 10%
11	1	C18	Ceramic Capacitor	GRM21BR61H106KE43L	805	muRata	10 μF, 50 V	Capacitor, Ceramic, 50 V, 10%
12	8	C38 C47−49 C53−55 C66	Ceramic Capacitor	GRM32ER71H106KA12L	1206	muRata	10 μF, 50 V	Capacitor, Ceramic, 50 V, 10%
13	5	C33 C39 C62 C65 C68	Ceramic Capacitor	/885012206083	603	Wurth	1 nF	Capacitor, Ceramic, 50 V, 10%
14	2	C10 C61	Ceramic Capacitor	/8853522100131	1808	Wurth	1 nF, Y2	HV Ceramic Capacitor, safety standard approved, 10%
15	4	C2 C4 C21 C23	Ceramic Capacitor	/885012206076	603	Wurth	1 μF, 25 V	Capacitor, Ceramic, 25 V, 10%
16	1	C12	Ceramic Capacitor	/885342206003	603	Wurth	2.2 nF, 200 V	Capacitor, Ceramic, SMD, 10%
17	1	C28	Ceramic Capacitor	GRM188C71E225KE11D	603	Murata	2.2 μF, 25 V	Capacitor, Ceramic, 25 V, 10%
18	1	C24	Ceramic Capacitor	GRM31CR61E226KE15L	1206	Murata	22 μF, 25 V	Capacitor, Ceramic, 25 V, 10%
19	1	C59	Ceramic Capacitor	/885012006054	603	Wurth	33 pF	Capacitor, Ceramic, 50 V, 5%
20	4	C34 C50 C56−57	Ceramic Capacitor	CM316X7S475K100AT	1206	Kyocera AVX	4.7 μF, 100 V	Capacitor, Ceramic, 100 V, 10%
21	1	C41	Ceramic Capacitor	/885012205054	402	Wurth	47 nF, 25 V	Capacitor, Ceramic, 25 V, 10%
22	1	C52	Ceramic Capacitor	GRM31CR61E476ME44L	1206	Murata	47 μF, 25 V	Capacitor, Ceramic, 25 V, 20%
23	1	C17	Ceramic Capacitor	/885012206077	603	Wurth	82 pF	Capacitor, Ceramic, 50 V, 10%
24	1	C22	Ceramic Capacitor	/885012206077	603	Wurth	nc	nc
25	1	C30	Ceramic Capacitor	C1608X5R1E475K080AC	603	TDK	nc	nc
26	1	C58	Ceramic Capacitor	GRM188R61E106KA73D	603	Murata	nc	nc
27	2	C71−72	Ceramic Capacitor	CL112J103J050	TH	KYET	nc	nc

Table 1. BOM (continued)

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
28	1	C44	Ceramic Capacitor	/885012206095	603	Wurth	nc	nc
29	2	D2 D9	Rectifier	S5JBF	SMBF	SHIKUES	5 A, 600 V	General Rectifier
30	1	DNR	Varistor	SVMH4532KA301PT401	4532	Shunlord	470 V	Varistor, 470 V
31	2	D12−13	Standard rectifier	4007	SOD123FL	std	0.8 A, 600 V	General Rectifier, 0.8 A, 600 V
32	6	D1 D3 D6 D15 D22−23	Ultrafast rectifier	ES1JFL	SOD123FL	**onsemi**	1 A, 600 V	Ultrafast Rectifier, 1 A, 600 V
33	1	D7	Schotty diode	S115FA	SOD123FL	**onsemi**	1 A, 150 V	Schotty diode, SMD
34	6	D8 D14 D16 D24 D27−28	Switching diode	BAS21HT1G	SOD323	**onsemi**	0.2 A, 250 V	Switching diode, SMD
35	5	D5 D10 D18 D19 D20	Schotty diode	BAT54HT1G	SOD323	**onsemi**	0.2 A, 30 V	Schotty diode, SMD
36	1	D4	Switching diode	nc	SOD523	**onsemi**	0.3 A, 75 V	nc
37	5	D11 D17 D21 D25−26	Switching diode	1N4148WT	SOD523	**onsemi**	0.3 A, 75 V	Switching diode, SMD
38	1	FB1	Ferrite bead		1210	Shunlord	nc	nc
39	1	FB2	Ferrite bead		1210	Shunlord	nc	nc
40	1	L1	Common filter	Custom	TH type	Custom	300 μH	T type, 12*6*4 MnZn core, 6T
41	1	L2	Common filter	SQ1515	TH type	Custom	18 mH	CM Filter, SQ1515, 10*13
42	1	F1	Micro Fuse	39215000000	Axial lead	Littlefuse	5 A, 250 Vac	Micro Fuse, 5 A/250 V
43	1	U14	LDO Regulator	NCP51460SN33T1G	SOT23	**onsemi**	5 V, 20 mA	LDO
44	4	Q2 Q5 Q7−8	NPN Transistor	MMBTA06LT1G	SOT23	**onsemi**	0.5 A, 80 V	General NPN Transistor, SMD
45	1	Q12	PNP Transistor	MMBT3906LT1G	SOT23	**onsemi**	0.2A, −40V	General PNP Transistor, SMD
46	1	U17	Voltage reference	NCP431ACSNT1G	SOT23	**onsemi**		PROGRAMMABLE PRECISION REFERENCE
47	1	U1	TPPFC controller	NCP1680	SO16	**onsemi**		TPPFC controller
48	1	U6	Syn. rectified controller	NCP4307FASNT1G	TSOP6	**onsemi**		Syn. rectified controller
49	2	U3−4	Driver GaN	NCP58922	QFN26	**onsemi**	78 mΩ	iGaN
50	2	U2 U13	Driver GaN	NCP58921	QFN26	**onsemi**	650 V, 50 mΩ	iGaN
51	1	U15	PWM controller	NCP1345Q01D1R2G	SOP9	**onsemi**		QR PWM controller
52	3	U5 U9 U12	HB Driver	NCP51530BMNTWG	DFN10	**onsemi**		HB Driver
53	4	Q11 Q13−15	Dual NMOS	2N7002V	SOT−563F	**onsemi**	60 V	Dual NMOS
54	1	Q1	MOSFET	FDMS4D0N12C	SO8FL	**onsemi**	120 V	MOSFET, NChan, 120 V
55	2	Q3−4	MOSFET	NTMT064N65S3H	Power88	**onsemi**	650 V, 64 mΩ	MOSFET, NChan, 650 V
56	2	NTC1−2	NTC	nc	603	Sunloard	nc	
57	2	U7−8	Optical coupler	FODM1009	LSOP4	**onsemi**		optical coupler, standard SOP package
58	1	Q20	PMOS	FDN5618P	SOT23	**onsemi**	60 V	60 V PMOS
59	1	L3	Toroidal Line Choke	T65125−100−080	TH type	std	100 μH	KoolMu Toroidal, T065125, 0.8 mm wire

Table 1. BOM (continued)

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
60	2	L5−6	SMD Inductor	MCL1608S4R7MT	603	Shunlord	4.7 μH	Inductor, SMD
61	1	L4	Inductor	PQ2618	TH type	Lihang, dongguan	140 μH	PQ2618, Ferroxcube 3C95 core, 12 Pin bobbin
62	1	T1	Transformer	PQ3218	TH type	Lihang, dongguan	380 μH	PQ3218, Ferroxcube 3C95,12 Pin Bobbin
63	1	R64	Resistor	Std	805	Std	0	Resistor, Chip, 1/8 W, 1%
64	2	R69 R105	Resistor	Std	402	Std	0	Resistor, Chip, 1/16 W, 1%
65	2	R31 R37	Resistor	Std	603	Std	1	Resistor, Chip, 1/10 W, 1%
66	1	R107	Resistor	Std	402	Std	1.6 K	Resistor, Chip, 1/16 W, 1%
67	8	R9−10 R36 R38 R43−45 R72	Resistor	Std	603	Std	10	Resistor, Chip, 1/10 W, 1%
68	7	R11 R13 R20 R29−30 R74 R95	Resistor	Std	603	Std	100 K	Resistor, Chip, 1/10 W, 1%
69	6	R35 R52−53 R24 R26 R59	Resistor	Std	402	Std	100 K	Resistor, Chip, 1/16 W, 1%
70	2	R60 R120	Resistor	Std	402	Std	10 K	Resistor, Chip, 1/16 W, 1%
71	1	R16	Resistor	Std	603	Std	150 K	Resistor, Chip, 1/10 W, 1%
72	1	R17	Resistor	Std	603	Std	15 K	Resistor, Chip, 1/10 W, 1%
73	4	R18 R48 R70−71	Resistor	Std	603	Std	1 K	Resistor, Chip, 1/10 W, 1%
74	1	R96	Resistor	Std	402	Std	2.4 K	Resistor, Chip, 1/16 W, 1%
75	1	R67	Resistor	Std	603	Std	2.7 K	Resistor, Chip, 1/10 W, 1%
76	1	R66	Resistor	Std	603	Std	200 K	Resistor, Chip, 1/10 W, 1%
77	1	R58	Resistor	Std	402	Std	20 K	Resistor, Chip, 1/16 W, 1%
78	1	R54	Resistor	Std	603	Std	22 K	Resistor, Chip, 1/10 W, 1%
79	1	R57	Resistor	Std	402	Std	22 K	Resistor, Chip, 1/16 W, 1%
80	1	R73	Resistor	Std	603	Std	510 K	Resistor, Chip, 1/10 W, 1%
81	1	R39	Resistor	Std	603	Std	300 K	Resistor, Chip, 1/10 W, 1%
82	2	R8 R47	Resistor	Std	603	Std	33	Resistor, Chip, 1/10 W, 1%
83	1	R109	Resistor	Std	402	Std	360	Resistor, Chip, 1/16 W, 1%
84	1	R56	Resistor	Std	402	Std	36 K	Resistor, Chip, 1/16 W, 1%
85	2	R2 R65	Resistor	Std	603	Std	390	Resistor, Chip, 1/10 W, 1%
86	2	R104 R106	Resistor	Std	402	Std	4.3 K	Resistor, Chip, 1/16 W, 1%
87	3	R7 R14 R55	Resistor	Std	603	Std	4.7	Resistor, Chip, 1/10 W, 1%
88	2	R33 R81	Resistor	Std	603	Std	470 K	Resistor, Chip, 1/10 W, 1%
89	1	R68	Resistor	Std	402	Std	5.1 K	Resistor, Chip, 1/16 W, 1%
90	2	R80 R82	Resistor	Std	603	Std	51 K	Resistor, Chip, 1/8 W, 1%
91	1	R108	Resistor	Std	402	Std	560	Resistor, Chip, 1/16 W, 1%
92	1	R63	Resistor	Std	402	Std	6.8 K	Resistor, Chip, 1/10 W, 1%
93	1	R61	Resistor	Std	402	Std	8.2 K	Resistor, Chip, 1/16 W, 1%
94	1	R32	Resistor	Std	603	Std	820	Resistor, Chip, 1/10 W, 1%
95	2	R50−51	Resistor	ERJ8BSFR12V	1206	Panasonic	0.12	Resistor, Chip, 1/2 W, 1%
96	1	R4	Resistor	ERJ8BSFR36V	1206	Panasonic	0.36	Resistor, Chip, 1/2 W, 1%
97	1	R3	Resistor	ERJ8BSFR39V	1206	Panasonic	0.39	Resistor, Chip, 1/2 W, 1%
98	2	R15 R19	Resistor	Std	1206	Std	2.7 K	Resistor, Chip, 1/4 W, 1%

Table 1. BOM (continued)

Item	Qty	Reference	Type	Part Name	Package	MFR	Value	Description
99	1	R12	Resistor	Std	1206	Std	22	Resistor, Chip, 1/4 W, 1%
100	6	R21−23 R25 R27−28	Resistor	Std	1206	Std	3.3 M	Resistor, Chip, 1/4 W, 1%
101	3	R40−42	Resistor	Std	1206	Std	7.5 M	Resistor, Chip, 1/4 W, 1%
102	1	C32	Electrolytic capacitor	OLKJ3552W151MF	18 mm × 35.5 mm	YMIN	150 μF, 450 V	size:18 mm × 35.5 mm
103	4	C13−14 C27 C51	Hybrid Electrolytic capacitor	EEHZS1H271UP	10*16.5	Panasonic	270 μF, 50 V	size: SMD10*16.5, ESR 13 mΩ
104	1	SW1	DIP switch	KF1027B−03P−G00−ON−01B	SMD	KAIFENG		SMD, 3P, 2.54 mm
105	1	J1	USB Type C connector	GT−USB−7010C	SMD	G−Switch		16 Pin, SMD
106	2	ZD1−2	Zener	MM3Z13VT1G	SOD323	**onsemi**	13 V	GENERIC ZENER−DIODE
107	1	ZD8	Zener	MM3Z24VT1G	SOD323	**onsemi**	24 V	GENERIC ZENER−DIODE
108	1	ZD5	Zener	MM3Z6V2T1G	SOD323	**onsemi**	6.2 V	GENERIC ZENER−DIODE

Simulated PD3.1 Daughter Card to Support PDO from 5 V to 48 V

No PD3.1 controller to support 48 V output in current market so a discrete circuit to simulate PD3.1 PDO from 5 V to 48 V output but no PD output Switch is used, daughter card interface is compatible with real PD3.1 controller.

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
36V	ON	OFF	OFF
48V	OFF	OFF	OFF

Figure 68. DIP SW Table

3 DIP switch combination (schematic shown in Figure 5) is decoded by 74HC238 to output Y0 − 7 to NMOS to Control feedback divider so 5 V/9 V/12 V/15 V/20 V/28 V/36 V/48 V is set, DIP SW set Vs output is as following table shown as Figure 68 the daughter card board photo is shown as Figure 69.

Figure 69. Daughter Card Photo

Simulated Card Operation Requirement

2SW Flyback Topology requires lowest input is large than N*Vo, lowest valley voltage is ~90 Vdc at 90 Vac and 12 V 5 A output with 150 μF Bulk capacitance (+/−20% tolerance), so PFC is allowed to not operate while 12 V output and start to operation while 15 V output, needs PD controller to controller PFC Vcc power on while 15 V or above output.

DIP switch needs to be set to 5 V every time while AC power on then change to other high voltage according to PD control, of cause, 5 V−12 V can also be set for AC power on because N*Vo < Vmin_dc during this output range. Any output can be set for AC power on while AC line is 230 Vac (N*48 V ≈ 1.414*230 Vac, N = 6.8)

Few Issues and Solved Solution While Using Simulated PD3.1 Daughter Card

a. 2SW Flyback topology needs Vin_min > Vo*Nps, so power supply may not operate while changing to high output from 5 V/9 V/12 V at 90 Vac and full load because PFC output slowly rises and results in OCP.

1. Temporary solution: change to high line first then change voltage from 5 V/9 V/12 V to higher voltage.
2. Final solution: PD controller sends out PFC on signal first then delay a time to change output voltage reference, this delay time (~300 ms in this design) is a PFC output rise time at 90 Vac and full load.

b. PFC only operates at 15 V−48 V, so there is a little high overshoot while output is changed from 5 V/9 V/12 V to 28 V/36 V/48 V because of step change of output reference and optical coupler's suppling voltage.

1. Final solution: PD controller changes internal voltage reference step by step during long time while output voltage is changed, so this issue can be solved by using PD protocol controller.

c. Voltage changed from 9 V to 28 V or 48 V to 28 V may be unsuccessful at large load because there is a large voltage drop on supplying optical−coupler voltage.

1. Temporary solution1: change output voltage under set low load (<0.2 A), then apply large load again.
2. Temporary solution2: change ZD8 to 30 V and C16 and C24 need to be changed to 35 V voltage rating but there will be a large power loss at no load and low efficiency at 0.25 W output while 28 V output.
3. Final solution: PD protocol controller's voltage reference changed step by step can solve this issue.

References

[1] **onsemi** datasheet for NCP1680, NCP1345, NCP51530, NCP4307, NCP58921, NCP58922, FDMS4D0N12C, NTMT064N65S3H

[2] **onsemi** Design Notes TND6412

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