

NCP1945, NCL38046 75 W Lighting Reference Design

TND6529/D

onsemi Devices	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1945LA NCL38046PA	LED Driver	90 to 305 Vac	75 W	Boost PFC, Quasi-resonant Flyback	Isolated

Evaluation Board Overview

This reference design covers the specification, design, and operation of the NCP1945 LED Driver demonstration board. This board features a 75 W Critical Conduction Mode (CRM) boost PFC with a quasi-resonant (QR) flyback. The secondary side is controlled by the NCL38046 constant current/ constant voltage controller. This secondary side controller allows for constant power limiting, which can prevent damage to an LED. This board takes advantage of several of the key features of the NCP1945 to demonstrate a LED driver that is capable of delivering less than 8% THD at 115 Vac – 277 Vac, while deep dimming down below 5% without any visible flickering on the LED.

This board is designed to be highly adjustable such that the user can explore a setup that will most closely match their application. In addition to the AC-input, the user can set the THD adjustment voltage, the output current setpoint, the constant power coefficient, constant power shape, and the dimming. The dimming on this board can be implemented in two separate ways. More details are provided about each of these features in their corresponding sections in this design note.

The Key Features of this Evaluation Board

- Integrated High-voltage Startup Circuit with Brownout Detection
- Integrated Input Filter Capacitor Discharge Capability
- Dual Range V_{CC} , with 150 V V_{CCH} Pin for Connection to High Voltage Aux Winding
- PFC Valley Synchronized Frequency Foldback
- Dynamic Response Enhancer
- THD Enhancer

Schematic

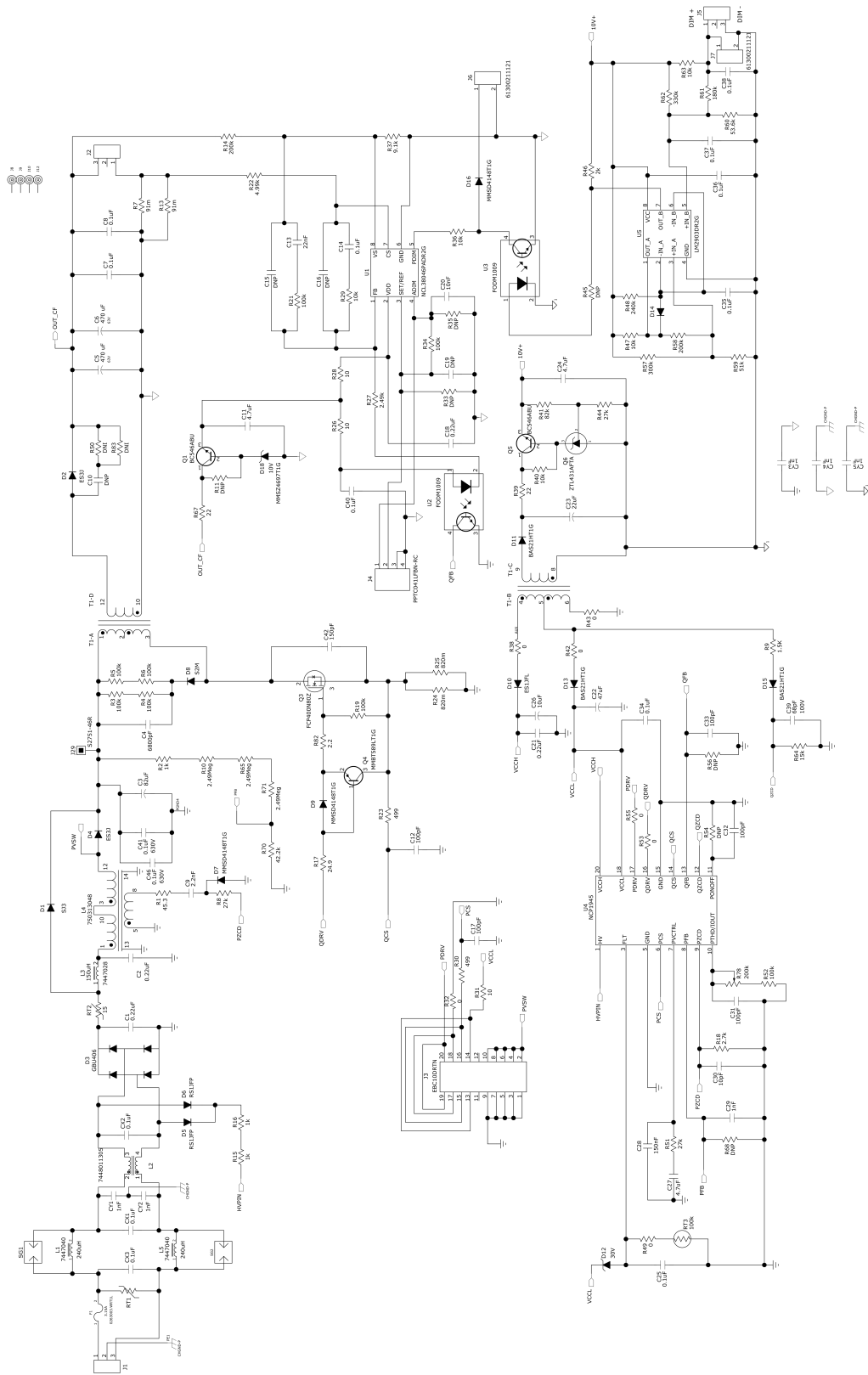


Figure 1. Motherboard Schematic

Board Pictures and Recommended Setup

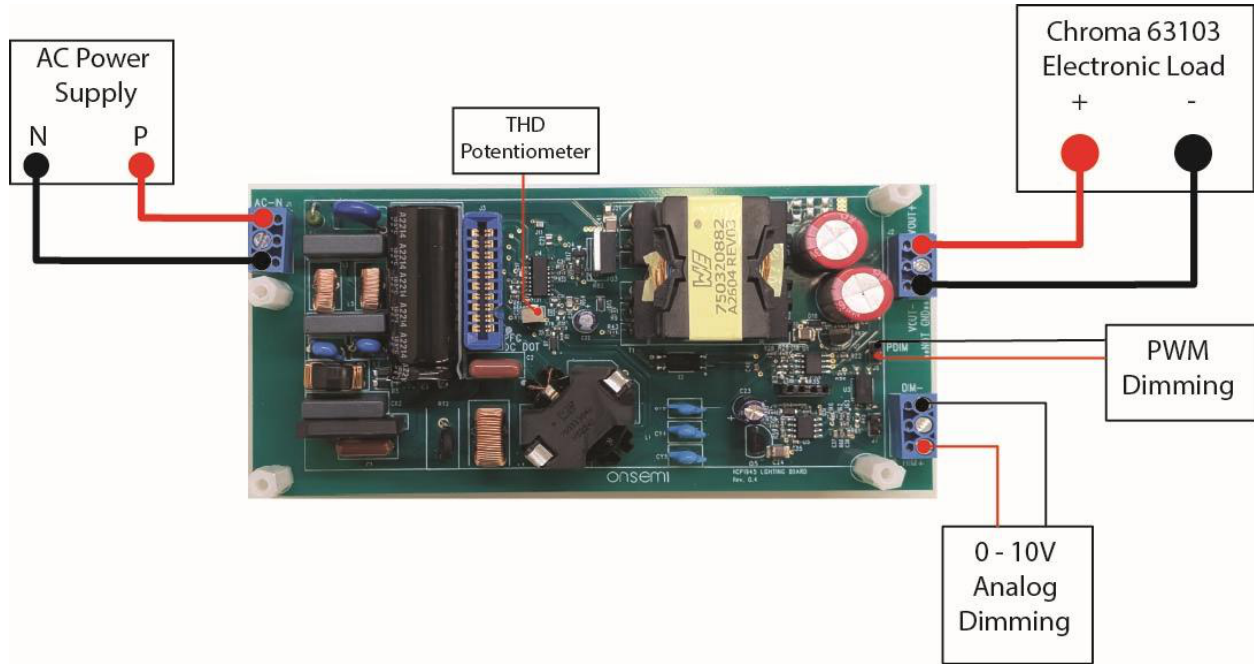


Figure 2. Motherboard and Potential Connections



Figure 3. Daughter Cards for the LED Driver

Figure 2 shows the Motherboard of the NCP1945 LED driver, and its inputs. The AC power supply connects to the left side of the board on J1. The board is capable of operating from 90 – 305 Vac. J2 is the terminal for the DC output. It can be connected directly to an LED load, or an e-load operating in CV mode. Please note that with some e-loads, there is potential for interaction between the control loop of the board and the control loop of the e-load. J6 and J7 are dimming signal connectors. J6 is for PWM dimming directly to the PDIM pin of the NCL38046. For an optimal

signal, a 200 Hz PWM is recommended. This allows for the most precise dimming behavior. J7 is the terminal for 0–10 V analog dimming. It is recommended to use the PWM dimming in this board for the best deep dimming. The performance data taken is with PWM dimming and with D11 removed.

The THD potentiometer allows the user to finely dial in the THD enhancer reference voltage. Through that adjustment, the amount of added time as “enhancement” can be tuned.

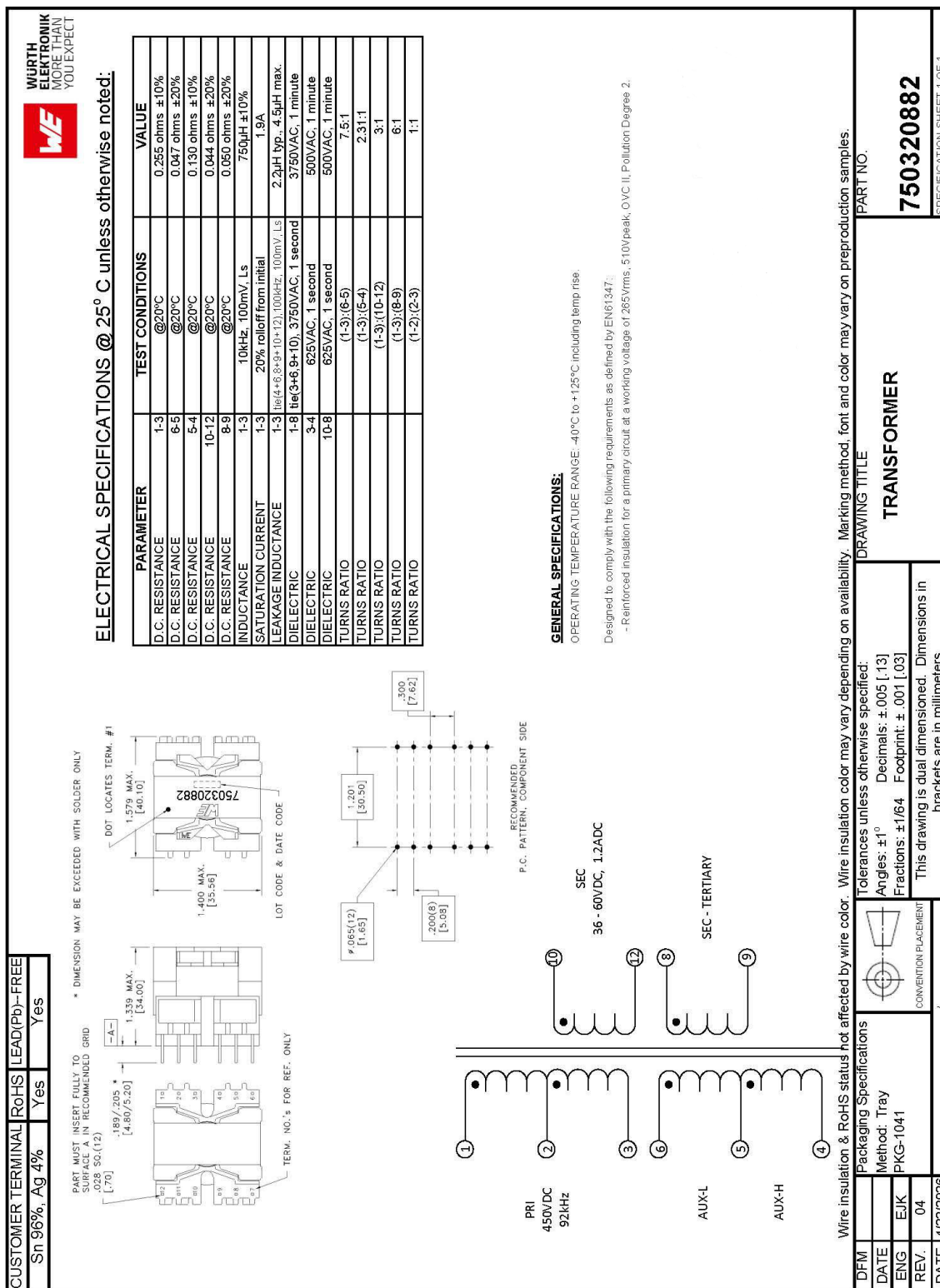


Figure 4. QR FB Transformer Specifications

PFC Inductor Specifications

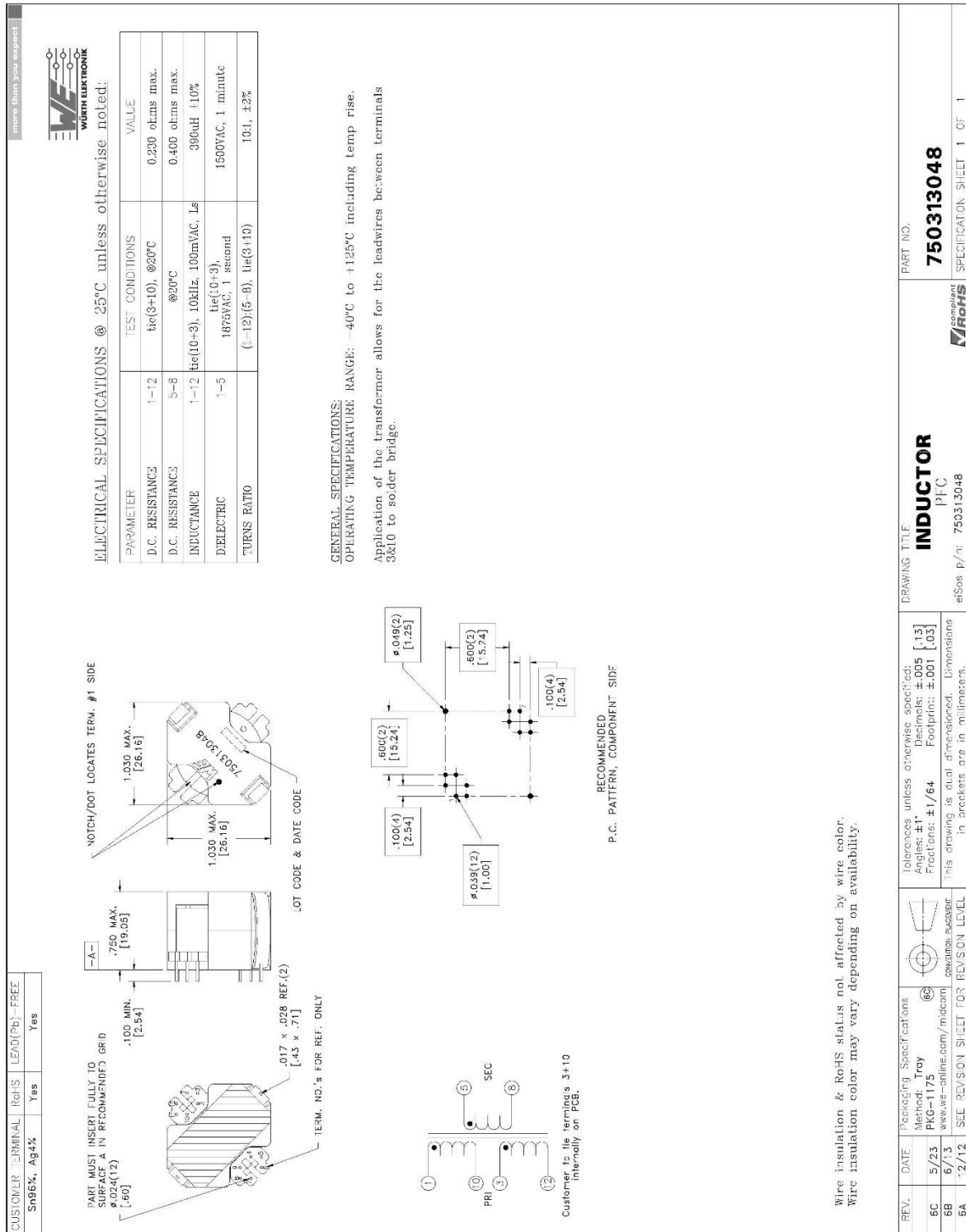


Figure 5. PFC Inductor Specifications

Key Features

THD Enhancer

The NCP1945LA controller used on this LED driver board incorporates a total harmonic distortion (THD) enhancement function that improves the input current waveform, particularly near the AC zero-crossing. This feature operates by increasing the PFC on-time where negative inductor current would otherwise distort the current profile. The amount of additional on-time is controlled through the PTHD pin, which enables external adjustment. On the evaluation board, this adjustment is implemented via a potentiometer (R78) that establishes a reference voltage, V_{ADJ} , using an internal 10 μ A current source. By varying the potentiometer resistance, the user modifies the comparator threshold within the THD enhancement circuit, thereby scaling the added on-time T_{ADJ} . This allows for flexible optimization of THD under different operating conditions.

Valley Synchronized Frequency Foldback

The NCP1945 PFC classically operates in critical conduction mode (CrM) until the power drops below a threshold level where the PFC stage enters the discontinuous conduction mode (DCM) with a dead time prolonged as the load further decays (frequency foldback). This novel technique also provides stable valley turn-on in both CrM and DCM for a maximized efficiency. In addition, the minimum frequency clamp (33 kHz typically) prevents audible frequencies, and the on-time is modulated to ensure near-unity power factor in both CrM and DCM operations.

Dual Range V_{CC} Management

LED driver applications are required to function across a wide range of output voltages, presenting a challenge for controllers that are self-biased from an auxiliary winding off of the flyback transformer. As the auxiliary winding voltage will typically scale proportionally with the output voltage, it is difficult to remain within the V_{CC} operating range of the controller across the entire output voltage operating range. For this LED driver, at standby, the output voltage is reduced to 12 V to be below the forward drop on the LEDs. This typically means an external linear regulator is required to bias the controller in standby conditions. The NCP1945 addresses this issue by incorporating two V_{CC} pins, V_{CCL} and V_{CCH} , capable of accepting up to 30 V and 150 V, respectively. The dual V_{CC} pins, which include a linear regulator between V_{CCH} and V_{CCL} , enable the NCP1945 to be biased with stacked auxiliary windings to meet the wide output operating range of the design.

Board Behavior

The NCP1945 LED driver demo board features 2 daughter cards. The first daughter card contains the PFC MOSFET as well as the drive circuitry. It plugs into socket J3 and the orientation of the daughter card is indicated

by a dot on the mother board that aligns with the dot the daughter card. Figure 3 shows close-up images of the boards and the alignment dots. The alignment of the daughter card should be ensured before powering up. Misalignment of the daughter card can cause damage to the motherboard and the daughter card.

The second daughter card on the LED driver demo board is the ADIM daughter card. This daughter card features a 10 switch DIP switch panel that sets the constant power functionality through the SET pin on the NCL38046. Refer to the section “constant power behavior” below for more details on how the CP functionality is implemented on this board. The other function of the ADIM daughter card is to set the ADIM resistance through the potentiometer R78. This sets the maximum setpoint for $V_{CS(REF)}$.

Constant Current/Constant Voltage Regulation

In typical operation, the NCP1945 LED driver board will regulate the current to the set level, and the output voltage is set by the forward drop of the LED load. However, this can lead to a situation where an incorrectly set current limit will cause the board to deliver enough power to damage the LED load. To prevent this from occurring, the NCL38046 features constant power regulation. The controller will reduce the current setpoint to maintain constant power. Figure 11 shows the constant power curve with the constant power coefficient (K_{CP}) set at 60%. During first power up, the NCL38046 detects the resistance and capacitance on the set pin. The detected Rset and Cset values determine the constant power coefficient. For ease of operation, there is a daughter card on the secondary side, that allows the user to set the Rset and Cset value.

The ADIM daughter card features 8 dip switches that let the user experiment with the constant power feature. It is recommended to operate at the 60% or 70% K_{CP} mark. The dip switches also let the user switch between linear and logarithmic dimming. Table 1 below indicates what each switch corresponds to. Please note that only one constant power coefficient should be used at a time, with the exception of linear/logarithmic switch.

Table 1. ADIM DAUGHTER CARD DIP SWITCH

Switch	Rset	Constant Power Coefficient
1	9.1 k Ω	40%
2	13 k Ω	50%
3	18 k Ω	60%
4	24 k Ω	70%
5	33 k Ω	80%
6	43 k Ω	90%
7	56 k Ω	100%
8	1.2 nF	Logarithmic

The NCL38046PA also allows for the maximum output current to be set externally through a voltage on the ADIM pin. After the initial Rset and Cset detection, the set pin is regulated to 3.3V. that voltage is then divided down through the variable resistor on the ADIM daughter card to set the pin voltage. The maximum current is delivered when there is 2.5 V on ADIM.

Constant Power Regulation

Typically, a 0–10 V analog dimming signal generator does not provide the full range of the dimming. For this

reason, this board is capable of taking a precise external dimming PWM signal, which allows the user to dim the LED both deeper, and with finer precision. With PWM dimming, this LED driver board can dim to less than 5% without visible flickering.

This demo board also features a basic 0–10 V dimming circuit intended to simulate common dimming circuits in the field. The data published in this report is taken with external PWM dimming. Figure 2 shows where the connections for PWM and analog 10 V dimming can be made.

Performance Graphs

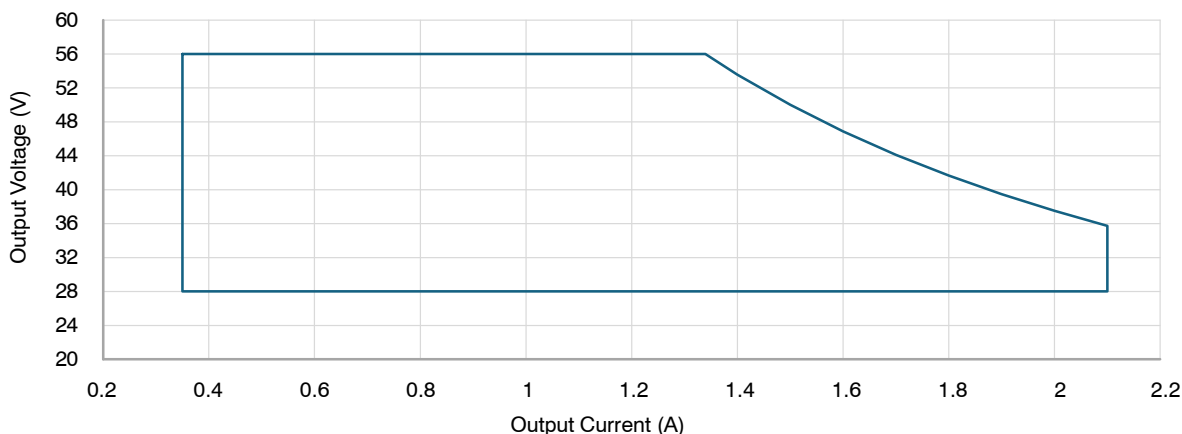


Figure 6. Window of Operation

The purpose of the window of operation curve is to show the limits of ideal operation on the NCP1945 LED driver. The board is designed to be able to deliver 75 W at 56 V to 36 V and deliver derated power from 36 V to 28 V. From

1.3 A, 56 V to 2.1 A, 36 V, the power is reduced such that 75 W is maintained throughout the constant power curve. It should be noted that this is an ideal curve, and the measured constant power curve can be found in Figure 11.

Efficiency Curves

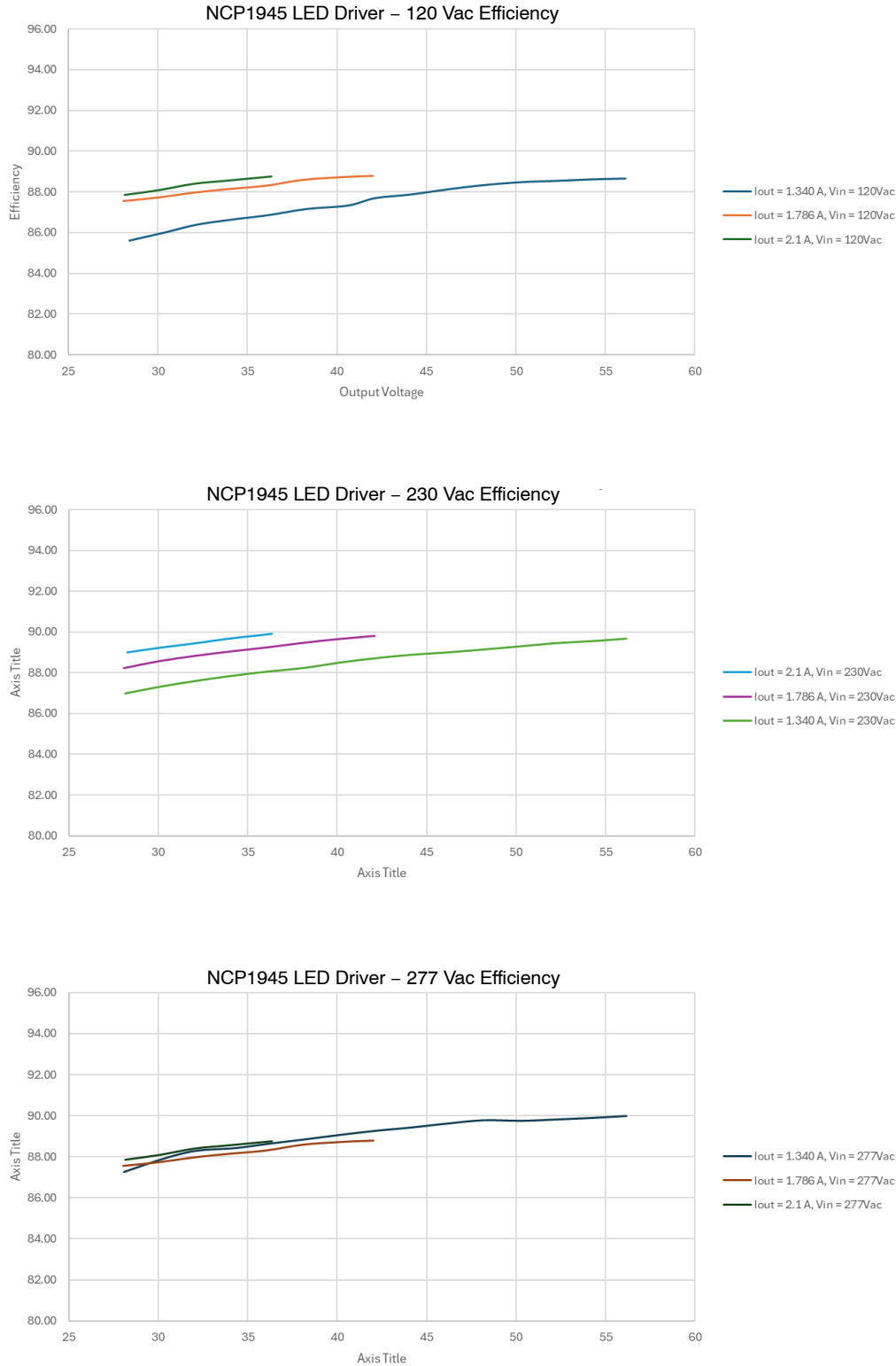


Figure 7. Efficiency Curves at 120 Vac, 230 Vac, 277 Vac

Power Factor

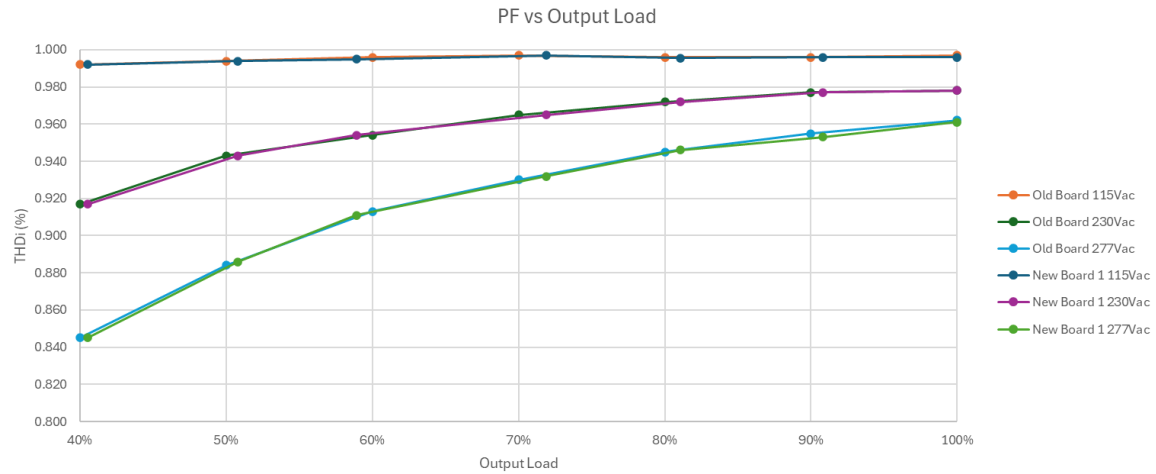


Figure 8. Power Factor

Current Total Harmonic Distortion (THDi)

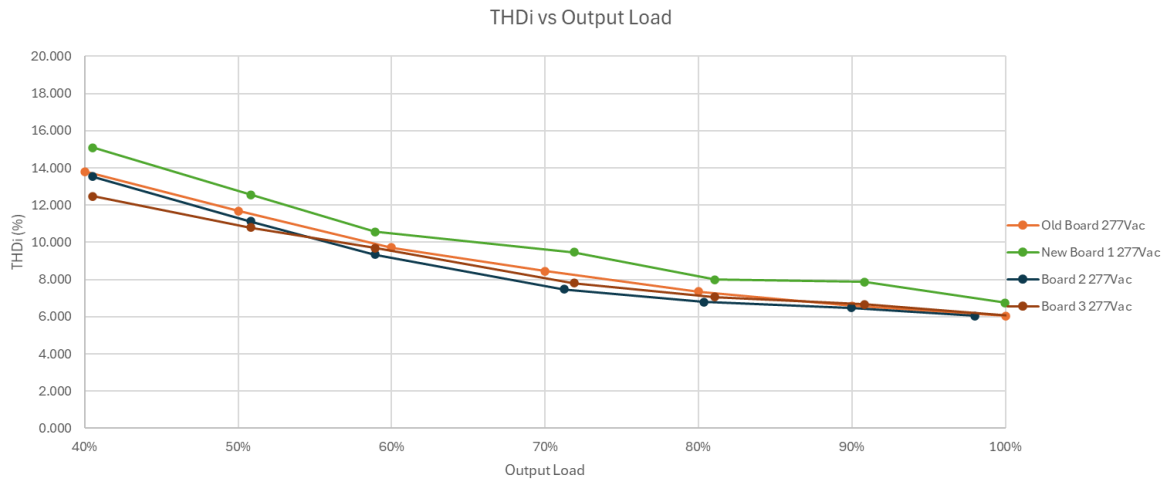


Figure 9. Current Total Harmonic Distortion

Dimming Curve

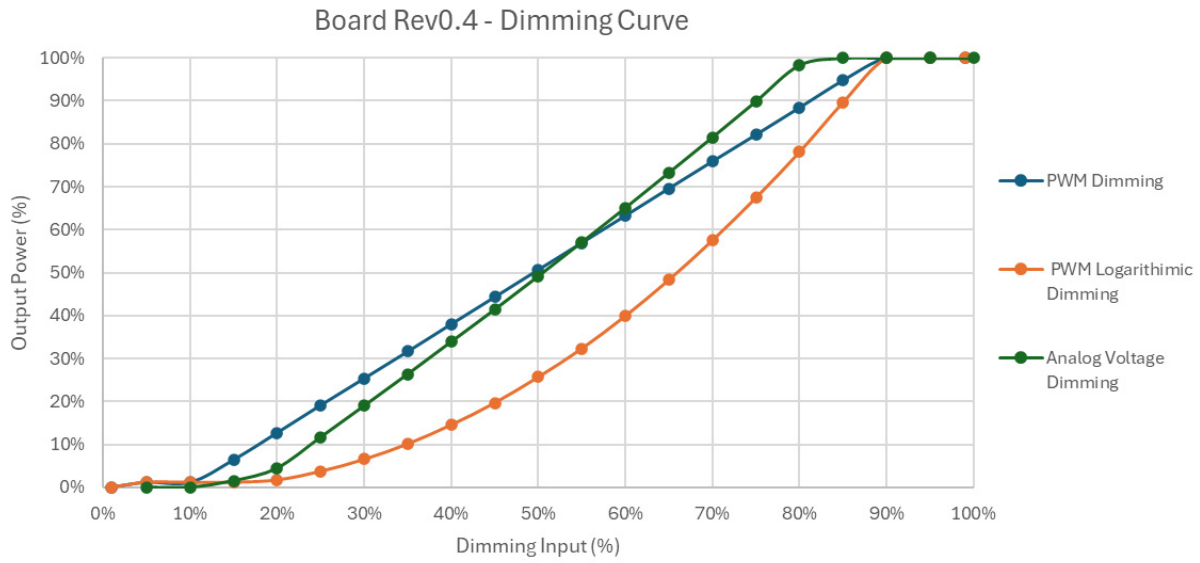


Figure 10. Dimming Curve

Constant Power Curve

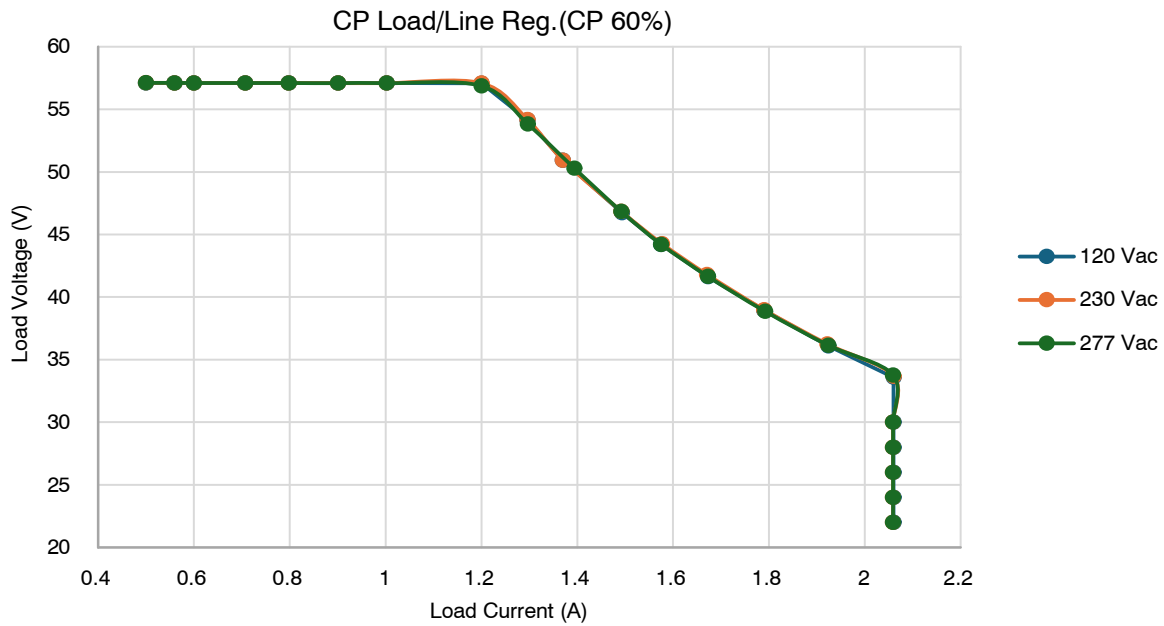


Figure 11. Constant Power Curve Across Line Levels

Waveforms

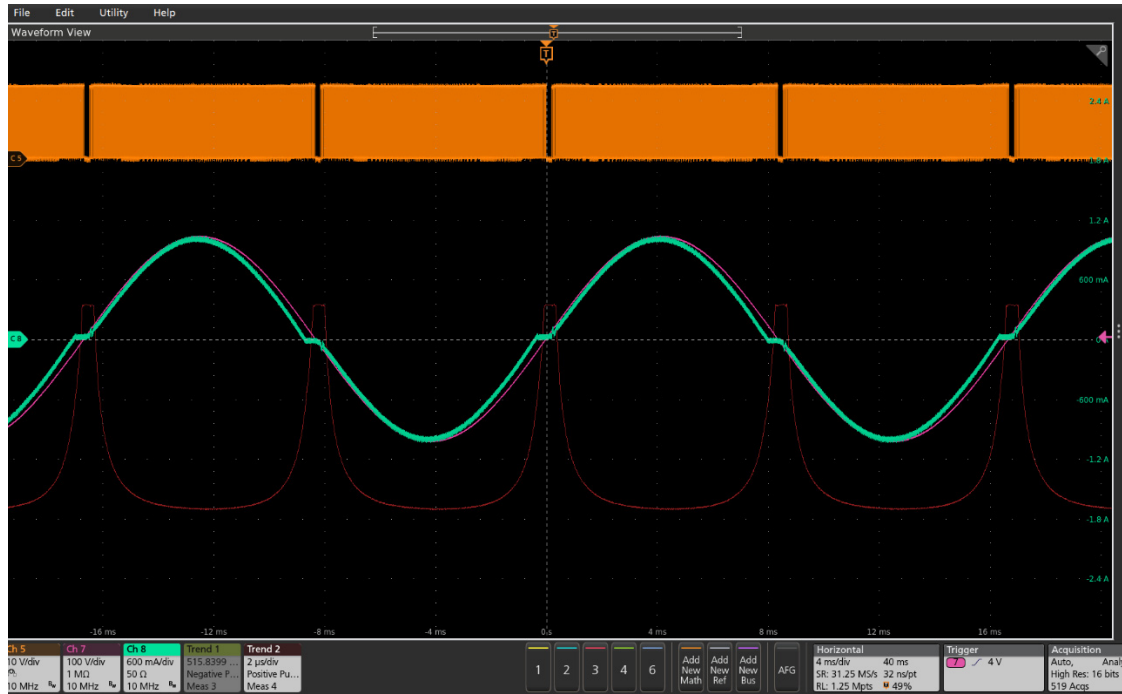


Figure 12. Waveform of the Line Current with THD Enhancer Functionality

The channels for the above waveform is as such: Ch 5: PDRV, Ch7: AC Voltage, Ch8: input Current, Trend 2: ON-time. It can be seen that the On-time is extended

significantly during AC zero cross, improving the shaping of the line current.

Layout

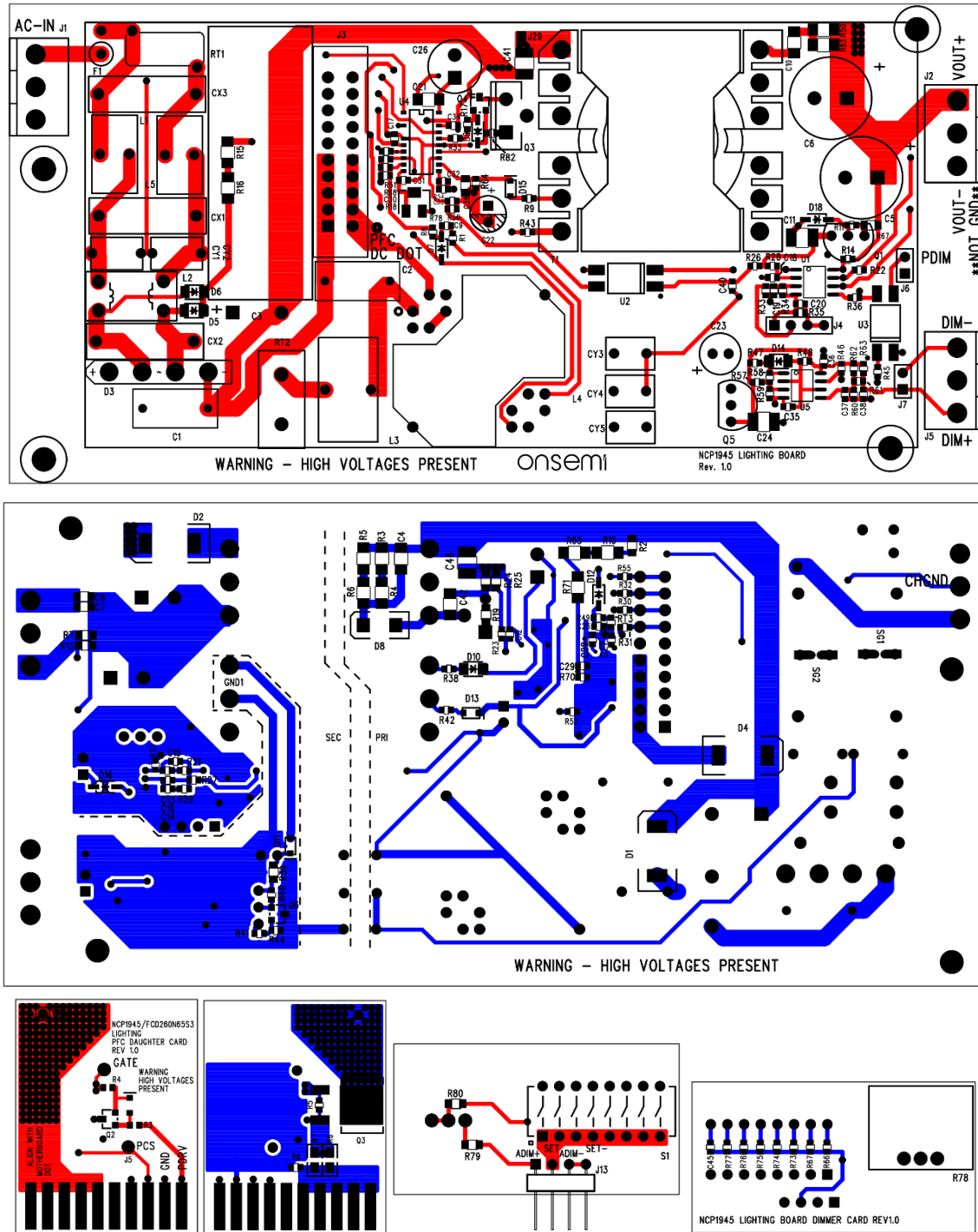


Figure 13. Layout of the Motherboard, PFC Daughter Card, and ADIM Daughter Card

Bill of Materials

Table 2. MOTHERBOARD BOM

Reference	Value	Description	Manufacturer Part Number
C3	82 μ F	CAP ALUM 82 μ F 20% 500 V RADIAL	500HXW82MEFR16X40
C4	6800 pF	CAP CER 6800 pF 630 V C0G 1206	C3216C0G2J682J115AA
C9	2.2 nF	CAP CER 2200 pF 25 V X7R 0603	CC0603KRX7R8BB222
C10	DNP		NA
C13	22 nF	CAP CER 0.022 μ F 50 V X7R 0603	CC0603KRX7R9BB223
C18	0.22 μ F	CAP CER 0.22 μ F 25 V X7R 0603	CGA3E1X7R1E224K080AC
C20	10 nF	CAP CER 10000 pF 25 V X7R 0603	CC0603KRX7R8BB103
C21	0.22 μ F	CAP CER 0.22 μ F 250 V X7R 1206	C1206C224KARACAUTO
C22	47 μ F	CAP ALUM 47 μ F 20% 35 V RADIAL	ESK476M035AC3EA
C23	22 μ F	CAP ALUM 22 μ F 20% 100 V RADIAL	ESK226M100AE3AA
C26	10 μ F	CAP ALUM 10 μ F 20% 160 V RADIAL TH	UVR2C100MPD
C27	4.7 μ F	CAP CER 4.7 μ F 25 V X5R 0603	C1608X5R1E475K080AC
C28	150 nF	CAP CER 0.15 μ F 25 V X7R 0603	885012206072
C29	1 nF	CAP CER 1000 pF 50 V X7R 0603	C0603C102K5RAC786
C30	10 pF	CAP CER 10 pF 50 V C0G/NPO 0603	CC0603JRNPO9BN100
C39	68 pF	CAP CER 68 pF 100 V C0G/NPO 0805	CC0805JRNPO0BN680
C42	150 pF	CAP CER 150 pF 1000 V X7R 1206	885342208016
C1-2	0.22 μ F	CAP FILM 0.22 μ F 5% 450 VDC RADIAL	ECW-F2W224JAQ
C11 C24	4.7 μ F	CAP CER 4.7 μ F 100 V X7R 1210	KAM32LR72A475KU
C12 C17 C31-33	100 pF	CAP CER 100 pF 25 V X7R 0603	CC0603KRX7R8BB101
C14 C25 C34-38 C40	0.1 μ F	CAP CER 0.1 μ F 50 V X7R 0603	C1608X7R1H104K080AA
C15-16 C19	DNP	NA	NA
C41 C46	0.1 μ F	CAP CER 0.1 μ F 630 V X7R 1210	C1210C104KBRACAUTO
C5-6	470 μ F	CAP ALUM 470 μ F 20% 63 V RADIAL TH	860020778021
C7-8	0.1 μ F	CAP CER 0805 0.1 μ F 63 V X7R 10%	C0805C104KMRECTU
CX1-3	0.1 μ F	CAP FILM 0.1 μ F 10% 310 VAC RADIAL	104MKP275K
CY1-2	1 nF	CAP CER 1 nF X1/Y2 400 V/250 V	C717U102MYVDBA7317
CY3-5	1 nF	CAP CER 1000 pF 250 VAC RADIAL	DE2E3SA102MN3AT02F
D1		DIODE GEN PURP 600 V 3 A SMC	SJ3
D3	600 V	BRIDGE RECT 1PHASE 600 V 4 A GBU	GBU406
D8	1 kV	DIODE GEN PURP 1 kV 2 A DO214AA	S2M
D12	30 V	DIODE ZENER 30 V 500 MW SOD123	MMSZ30T1G
D18	10 V	DIODE ZENER 10 V 500 MW SOD123	MMSZ4697T1G
D10 D14		DIODE GEN PURP 600 V 1 A SOD123F	ES1JFL
D11 D13 D15		DIODE STANDARD 250 V 200 MA SOD323	BAS21HT1G
D2 D4		DIODE SUPERFAST SMC 600 V 35 ns	ES3J
D5-6		DIODE GP 600 V 1.2 A SOD123HE	RS1JFP
D7 D9 D16	100 V	DIODE GEN PURP 100 V 200 MA SOD123	MMSD4148T1G
F1	3.15 A	FUSE BOARD MOUNT 3 A 250 VAC AXIAL	0263003.WRT1L
J3		CONN EDGE DUAL FEMALE 20 POS 0.100	EBC10DRTN



Table 2. MOTHERBOARD BOM (continued)

Reference	Value	Description	Manufacturer Part Number
J4		CONN HDR 4 POS 0.1 TIN PCB	PPTC041LFBN-RC
J29		PC TEST POINT SMD_2 x 1.2 mm	S2751-46R
J1-2 J5		Terminal Block, Vertical, 300 V, 15 A, 3 pin, 5 mm Spacing	ED100/3DS
J6-7		CONN HEADER VERT 2 POS 2.54 mm	61300211121
L2	5 mH	CMC 5 mH 1.3 A 2LN TH	7448011305
L3	150 μ H	FIXED IND 150 μ H 1 A 130 M Ω TH	7447028
L4	390 μ H	Inductor, Coupled, 390 μ H, Pri DCR-400 m Ω	750313048
L1 L5	240 μ H	TOROIDAL LINE CHOKE 240 μ H, 1 A	7447040
Q3		MOSFET N-CH 800 V 14 A TO220-3	FCP400N80Z
Q4		TRANS PNP 30 V 1 A SOT23-3	MMBT589LT1G
Q6		Adjustable Shunt Regulator	ZTL431AFTA
Q1 Q5		TRANS NPN 65 V 0.1 A TO92-3	BC546ABU
R1	45.3 Ω	RES 45.3 Ω 1% 1/10 W 0603	RC0603FR-0745R3L
R2	1 k Ω	RES 1 k Ω 1% 1/8 W 0805	RC0805FR-071KL
R9	1.5 k Ω	RES SMD 1.5 k Ω 1% 1/10 W 0603	AC0603FR-071K5L
R17	24.9 Ω	RES 24.9 Ω 1% 1/10 W 0603	RC0603FR-0724R9L
R18	2.7 k Ω	RES 2.7 k Ω 1% 1/10 W 0603	RC0603FR-072K7L
R19	100 k Ω	RES 100 k Ω 1% 1/8 W 0805	RC0805FR-07100KL
R22	4.99 k Ω	RES 4.99 k Ω 1% 1/10 W 0603	AC0603FR-134K99L
R27	2.49 k Ω	RES 2.49 k Ω 1% 1/10 W 0603	RC0603FR-072K49L
R31	10 Ω	RES 10 Ω 1% 1/10 W 0603	RC0603FR-1010RL
R37	9.1 k Ω	RES 9.1 k Ω 1% 1/10 W 0603	RC0603FR-079K1L
R41	82 k Ω	RES 82 k Ω 1% 1/10 W 0603	RC0603FR-0782KL
R46	2 k Ω	RES 2 k Ω 1% 1/10 W 0603	RC0603FR-072KL
R48	240 k Ω	RES 240 k Ω 1% 1/10 W 0603	RC0603FR-07240KL
R56	DNP	NA	NA
R57	300 k Ω	RES 300 k Ω 1% 1/10 W 0603	RC0603FR-07300K
R59	51 k Ω	RES 51 k Ω 1% 1/10 W 0603	RC0603FR-0751KL
R60	53.6 k Ω	RES 53.6 k Ω 1% 1/10 W 0603	311-53.6KHRCT-ND
R61	180 k Ω	RES 180 k Ω 1% 1/10 W 0603	RC0603FR-07180KL
R62	330 k Ω	RES 330 k Ω 1% 1/10 W 0603	RC0603FR-07330KL
R64	15 k Ω	RES 15 k Ω 1% 1/10 W 0603	RC0603FR-0715KL
R68	DNP	RES 0 Ω JUMPER 1/10 W 0603	RC0603FR-070RL
R70	42.2 k Ω	RES 42.2 k Ω 1% 1/10 W 0603	RC0603FR-0742K2L
R78	200 k Ω	TRIMMER 200 k Ω 0.25 W GW TOP	3224X-1-204E
R82	2.2 Ω	RES 2.2 Ω 1% 1/10 W 0603	RC0603FR-072R2L
R10 R65 R71	2.49 M Ω	RES, SMD, 1/4 W	RC1206FR-072M49L
R11 R33 R35 R45 R54	DNP	NA	NA
R14 R58	200 k Ω	RES 200 k Ω 1% 1/10 W 0603	RC0603FR-07200KL
R15-16	1 k Ω	RES 1 k Ω 1% 1/4 W 1206	RC1206FR-071KL
R21 R34 R52	100 k Ω	RES 100 k Ω 1% 1/10 W 0603	RC0603FR-07100KL



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Table 2. MOTHERBOARD BOM (continued)

Reference	Value	Description	Manufacturer Part Number
R23 R30	499 Ω	RES 499 Ω 1% 1/10 W 0603	RC0603FR-07499RL
R24–25	820 m Ω	RES 0.82 Ω 1% 1/8 W 0805	RL0805FR-070R82L
R26 R28	10 Ω	RES 10 Ω 1% 1/10 W 0603	RC0603FR-0710RL
R29 R36 R40 R47 R63	10 k Ω	RES 10 k Ω 1% 1/10 W 0603	RC0603FR-0710KL
R3–6	100 k Ω	RES 100 k Ω 1% 1/4 W 1206	RC1206FR-13100KL
R32 R38 R42–43 R49 R53 R55	0 Ω	RES 0 Ω JUMPER 1/10 W 0603	RC0603JR-070RL
R39 R67	22 Ω	RES 22 Ω 1% 1/8 W 0805	RC0805FR-0722RL
R50 R83	DNI	RES, SMD, 1/4 W	
R7 R13	91 m Ω	RES 0.091 Ω 1% 1/3 W 0805	UCR10EVHFSR091
R8 R44 R51	27 k Ω	RES SMD 27 k Ω 1% 1/10 W 0603	AC0603FR-0727KL
RT1		VARISTOR 470 V 3.5 kA DISC 10 mm	B72210S2301K101
RT2	15 Ω	Thermistor, NTC	B57153S0150M000
RT3	100 k Ω	THERM NTC 100 k Ω 3950K 0603	SDNT1608X104F3950FTF
SG1–2	2 kV	Spark gap, 8 mil. 2 kV arc.	NA
T1		Custon xfmr RM10/PQ3230	
U1		CC/CV AMPLIFIER FOR PRECISE CC R	NCL38046PADR2G
U4		ACF PWM Controller	NCP1945
U5		IC COMPARATOR 2 GEN PUR 8SOIC	LM2903DR2G
U2–3	NA	OPTOISOLATOR 5 kV 1CH TRANS 4-SOP	FODM1009

Table 3. PFC DAUGHTER CARD BOM

Reference	Value	Description	Manufacturer Part Number
D1		DIODE GEN PURP 100 V 200 MA SOD323	BAS16HT1G
J4		Testpin, Gold, 40 mil	3103-2-00-21-00-00-08-0
J1 J5		TEST POINT PC MINI RED	5000
Q2		TRANS PNP 30 V 1 A SOT23-3	MMBT589LT1G
Q3		MOSFET N-CH, 650 V, 12 A, 260 m Ω	FCD260N65S3
R3	10 Ω	RES 10 Ω 1% 1/10 W 0603	RC0603FR-0710RL
R4	4.99 Ω	RES 4.99 Ω 1% 1/10 W 0603	RC0603FR-074R99L
R5	49.9 k Ω	RES 49.9 k Ω 1% 1/10 W 0603	RC0603FR-0749K9L
R8	0 Ω	RES, SMD, 1/10 W	RC0603FR-070RL
R6–7	280 m Ω	RES 0.28 Ω 1% 1/3 W 0805	RLC73K2AR28FTD



Table 4. ADIM DAUGHTER CARD BOM

Reference	Value	Description	Manufacturer Part Number
C45	1000 pF	CAP CER 1000 pF 50 V C0G/NP0 0603	C0603C102J5GAC7867
J13		Connector, Header, RA, 100 mil spacing, Post 120 mil, Mate 230 mil	68016-204HLF
R66	9.1 k Ω	RES 9.1 k Ω 1% 1/10 W 0603	RC0603FR-079K1L
R67	13 k Ω	RES 13 k Ω 1% 1/10 W 0603	RC0603FR-0713KL
R73	18 k Ω	RES SMD 18 k Ω 1% 1/10 W 0603	AC0603FR-0718KL
R74	24 k Ω	RES 24 k Ω 1% 1/10 W 0603	RC0603FR-0724KL
R75	33 k Ω	RES 33 k Ω 1% 1/10 W 0603	RC0603FR-0733KL
R76	43 k Ω	RES 43 k Ω 1% 1/10 W 0603	RC0603FR-0743KL
R77	56 k Ω	RES 56 k Ω 1% 1/10 W 0603	RC0603FR-0756KL
R78	250 k Ω	POT 250 k Ω 2 W CERMET LINEAR	91A1A-B28-A22L
R79	62 k Ω	RES 62 k Ω 1% 1/8 W 0805	RC0805FR-0762KL
R80	0 Ω	RES 0 Ω JUMPER 1/8 W 0805	RC0805JR-070RL
S1		SWITCH SLIDE DIP SPST 0.1 A 24 V, 0.878 Length	1825057-7



REVISION HISTORY

Revision	Description of Changes	Date
0	Initial document release.	8/12/2026

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