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DN05050/D

12 V/18 W Hi-Power Factor Constant Voltage LED Driver

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DESIGN NOTE

Table 1. DEVICE DETAILS

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCL30000	LED Lighting	200−305 Vac	18 W	Flyback	Yes

Table 2. OTHER SPECIFICATIONS

Output Voltage	12 V
Ripple	1.4 V pk−pk
Nominal Current	1.5 A
Current Limit	2.0 A
Min Current	0
Typical Power Factor	0.98
Typical THDi	15.3%
Typical Efficiency	84.7%
Inrush Limiting/Fuse	1 A Fuse

Circuit Description

Normally high power factor LED drivers provide a regulated constant current output to drive a string of LEDs. In certain circumstances, the LED load may have a built in constant current LED driver so all that is need to drive the LED load is a power factor corrected constant voltage driver commonly referred to as an LED Power Supply. It is common for these supplies to generate 12 V, 24 V or even a higher voltage.

The focus of this design note is the development of an isolated offline, high power factor corrected single stage constant voltage supply which supports AC mains from 200−305 Vac. This addresses AC line voltages found in many parts of the world as well as the 277 Vac commercial input required for the United States.

Specifically this power supply is suitable for 12 V LED lamps used for retail, hotels, reception areas, art galleries, museums, and residential installations including landscape lighting. The constant output voltage with high power factor and compact size provides a driver solution suitable for many applications.

An example 850 lumen LED lamp manufactured by Megaman is the AR111 which draws 15 W with a rated life of 25,000 hours. The narrow beam angle provides center beam illuminance of 5000 candela. Performance is comparable to a 75 W halogen lamp which typically provides only 1/10th the lifetime.

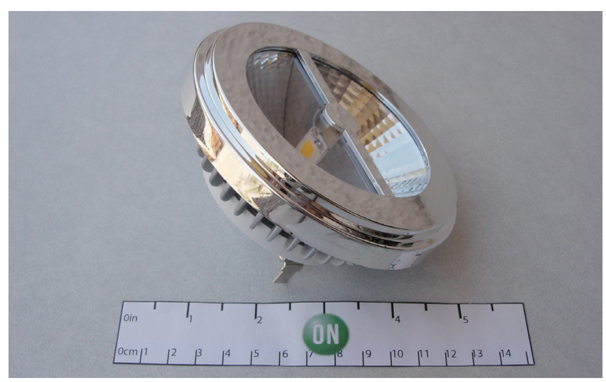

Figure 1. AR111 − LED Lamp

Shown below are the design guidelines for this driver:

- Input Range: 200−305 Vac
- Output Voltage: 12 V
- Output Current: 1.5 A Continuous
- Peak Current: 2.0 A
- Efficiency: > 83%
- Power Factor: > 0.95

- Isolated Output
- Overload Protection

The NCL30000LED3GEVB demonstration board serves as the basis for this application. This demo board was selected as it provides high input voltage covering 277 V applications with applicable tolerance. The low profile design provides a compact solution. The high efficiency of this converter minimizes thermal issues. With a few modifications, this demo board will provide constant voltage control and exceed the performance objectives.

Several component changes are required to optimize the demo board for constant voltage operation. Key changes are outlined below.

The power transformer was designed with dual secondary windings. The demo board is shipped with the secondary windings connected in a series configuration to support higher output voltage. Changing the windings to a parallel configuration optimizes the transformer for this 12 V application. The demo board readily supports this by relocating transformer lead “FL3” to PCB hole “H2” and lead “FL2” to hole “H5”.

Higher transformer secondary current and lower voltage allows use of a Schottky rectifier which lowers power loss and improves efficiency. The ON Semiconductor NTSJ20100 is a good choice and can be fitted to the back of the demo board by forming leads to fit the DPAK PCB pattern.

High power factor single stage converters generally have no energy storage in the primary side circuit. As such, storage is required on the secondary side and typically in the form of capacitance in parallel with the load. Ripple voltage is nearly sinusoidal at twice the applied ac input frequency. The ripple amplitude is inversely proportional to the total capacitance, thus increasing the filter capacitance will reduce ripple voltage.

Output capacitors C11 and C12 are replaced with a lower voltage rating providing higher capacitance in the same size device reducing ripple for this higher output current application. The 1,500 μF, 16 V capacitors are a direct fit on the board.

On the original demo board, dual loop control is used to regulate a constant current. For this constant voltage application, the feedback will be modified to use one half of the dual op amp for voltage control and the other as current limit.

A marked up schematic is presented in Figure 2. This shows changes to the demo board in red. Component changes are listed below. Rework details are shown in Figures 3 and 4:

- R26 = 0 Ω
- C14 = 1 μF
- R27 = 3.3 kΩ
- R28 = 160 Ω
- C15 = 100 pF
- R29 = 0.05 Ω (Stack Two 0.1 Ω Resistors)
- Remove R31. Scrape soldermask off PCB trace as shown in detail. Install R32 between scraped area and pad of R31 as shown in detail.
- Place insulating tape over unused PCB pad for R31 as shown. Locate R31 = 6.2 kΩ from uncovered pad of R31 to pad of R29 as shown in detail.

The demo board includes over voltage protection which was originally set at ~57 V for high voltage LED applications. The threshold must be reduced to activate at a lower voltage. This protects the output capacitors.

- D12 = 13 V Zener
- R24 = 1 kΩ

On-time capacitor C9 controls the minimum ac line input voltage which will provide full output power. The peak transformer current must be reduced to operate the demo board transformer at this 12 V level to avoid saturation. Change C9 to 470 pF.

In this example, the existing transformer on the demo board was used, if a new transformer was designed this would allow operation at 18 W for input voltages well below 200 Vac. It is possible to extend the input voltage down to 90 Vac.

Converter startup time is controlled by the bias capacitor C8 and the startup resistors. For this application, the startup resistors R12 and R13 were increased in value to reduce dissipation and improve efficiency. This increases the converter startup time somewhat.

Measured data shows the power factor exceeds the target value of 0.95 at 305 Vac and is above 0.97 for input voltage lower than 264 Vac. See Figure 5.

Line voltage regulation and efficiency curves are shown in Figure 6. Note the tight voltage regulation and high efficiency exceeding 84% below 277 Vac input.

A bill of materials is provided in Table 3. The highlighted components are those which must be changed relative to the standard demo board.

Design Optimization

There are some options to improve efficiency of this power supply. The standard demo board transformer was designed for applications higher than 12 V operation. Using the NCL30000 Design Worksheet, values specific to a particular application can be entered. Changing the turns ratio and wire size can lower peak current which will improve efficiency.

Another power saving option is reducing the losses due to the output rectifier. The Schottky rectifier suggested in this design note provides lower loss compared to a standard rectifier, however a synchronous rectifier approach similar to that outlined in DN05035/D could provide additional efficiency improvement.

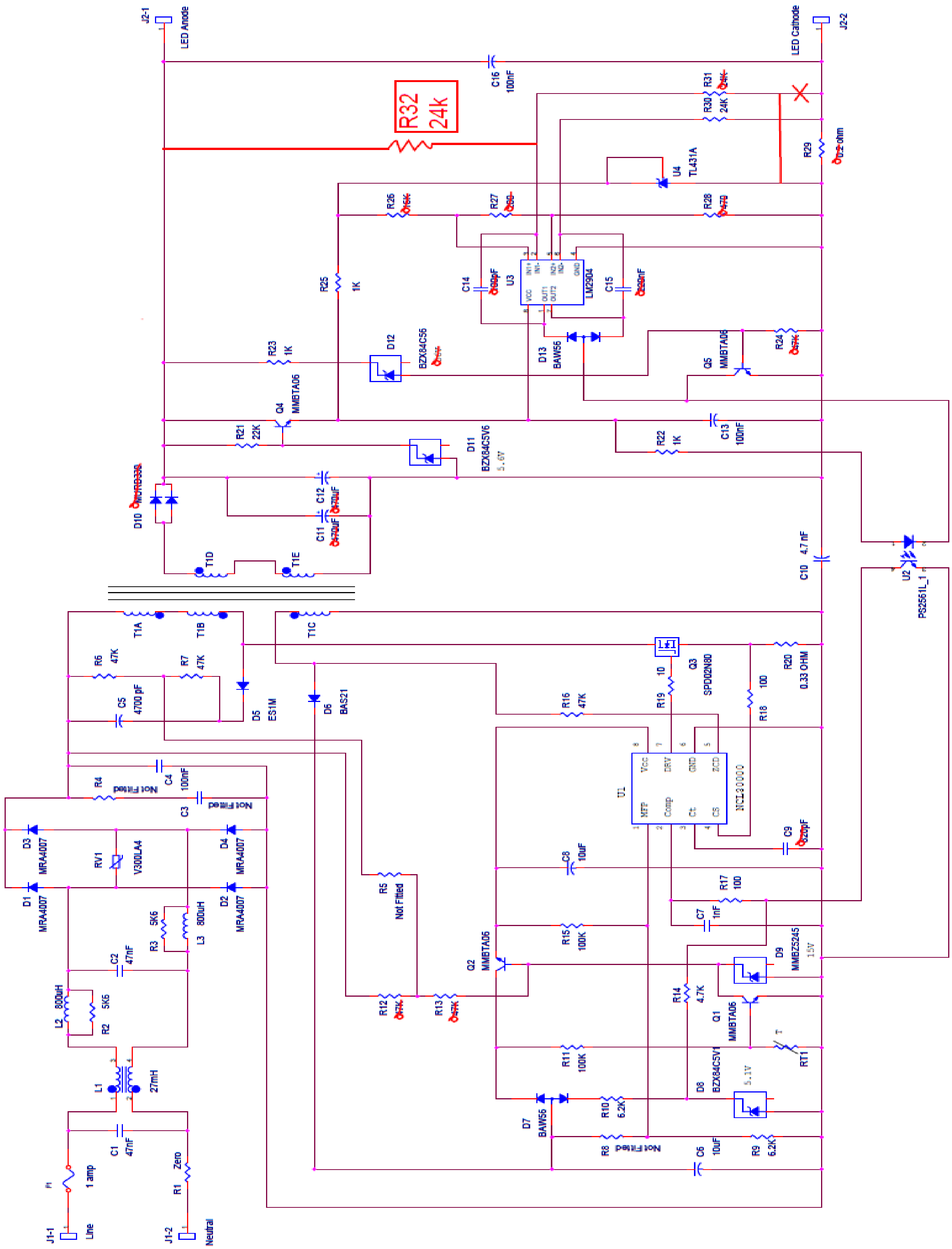

Figure 2. Marked Up Schematic

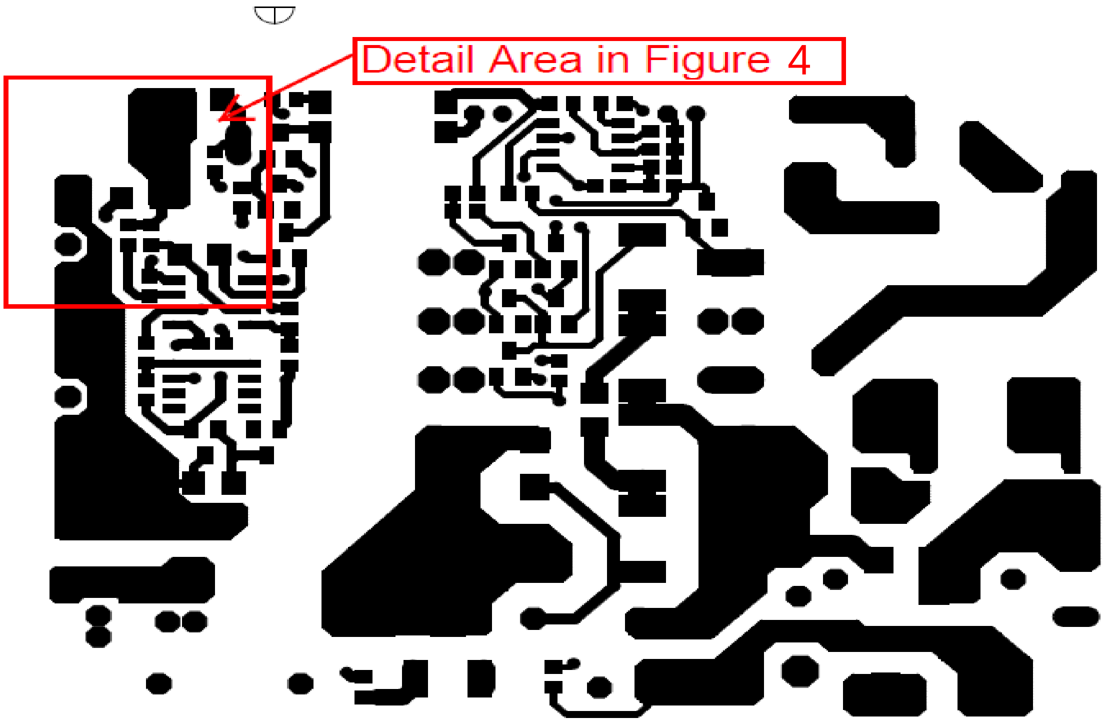

Figure 3. Demo Board Bottom Side Copper

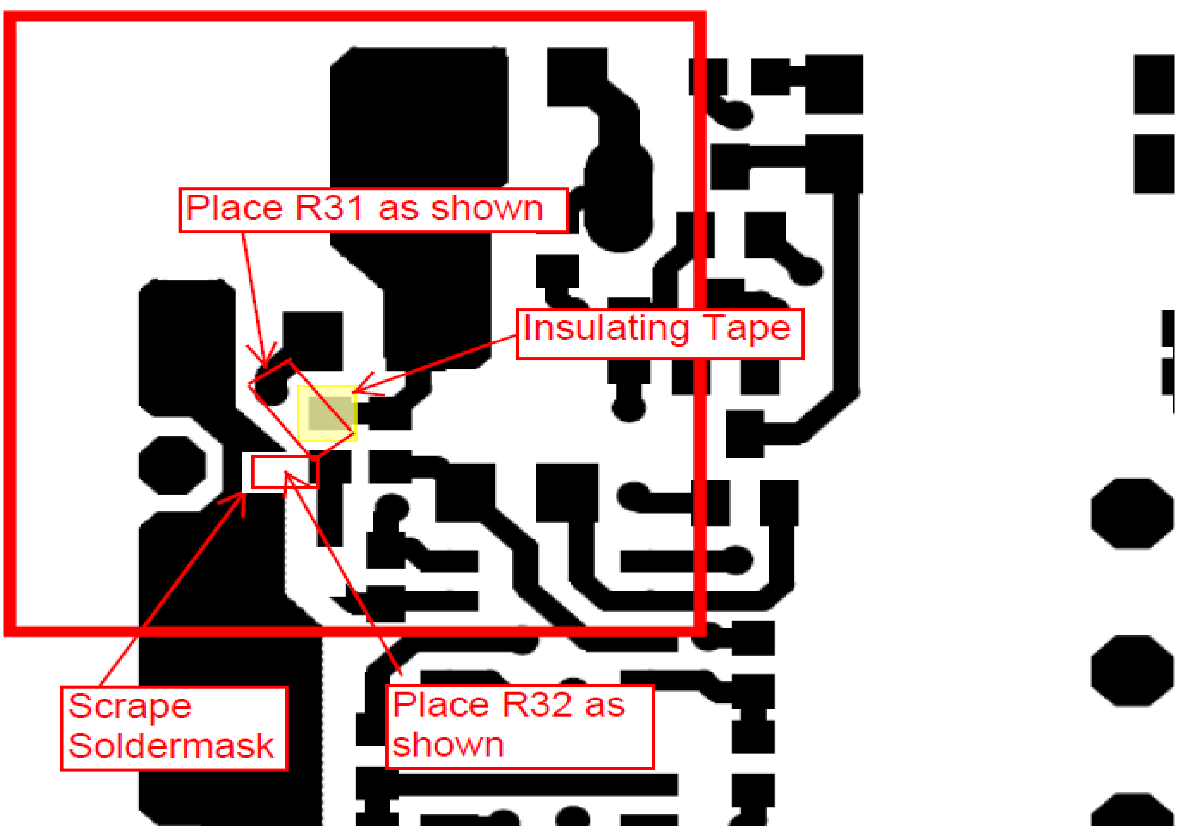

Figure 4. Detail of Rework Area in Figure 3

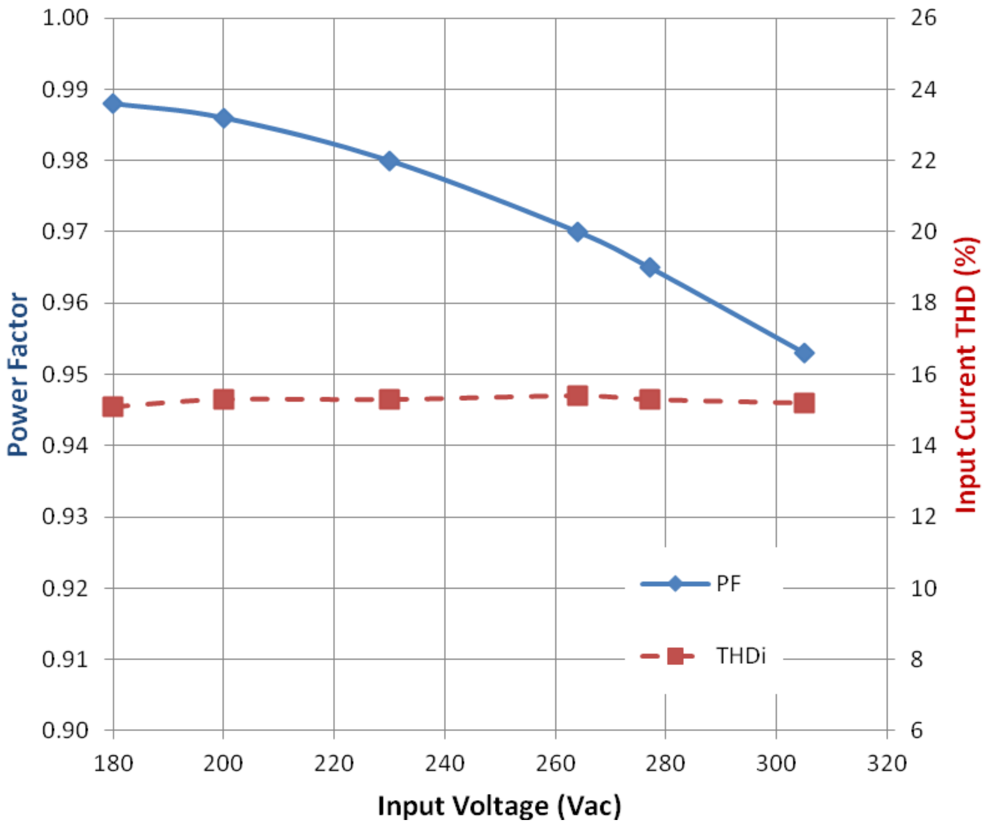

Figure 5. Power Factor and THDi

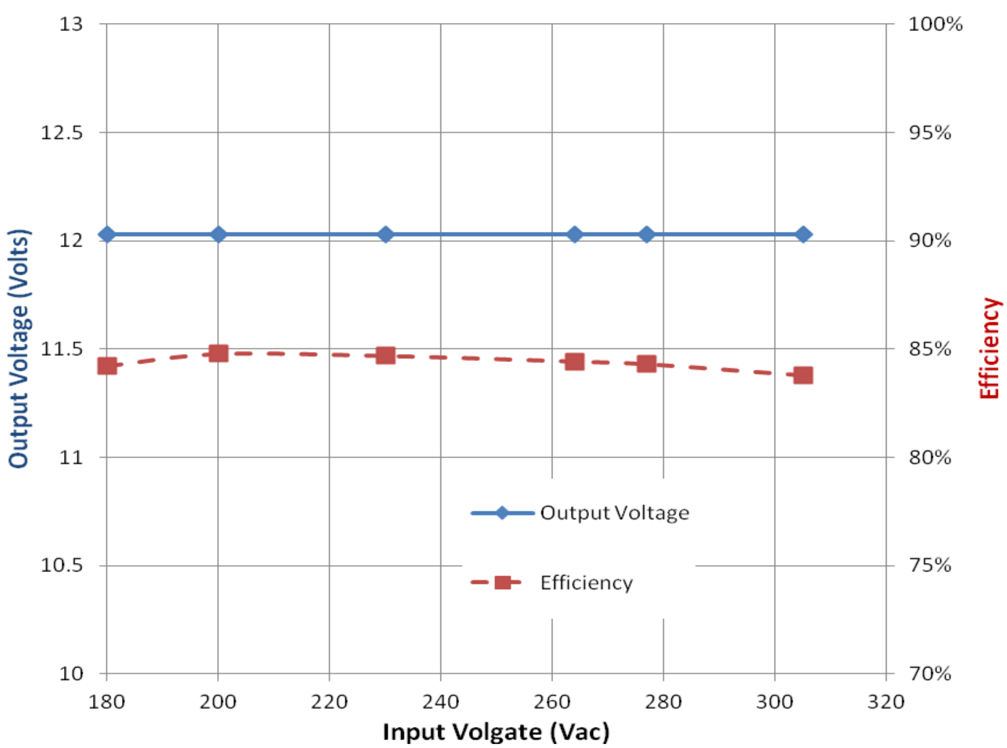

Figure 6. Current Regulation and Efficiency

Table 3. BILL OF MATERIALS (Changes to Demo Board Highlighted)

Designator	Value	Description	Footprint	Manufacturer	Part Number
C1, C2	47 nF	300 VAC X1 Polyester Film	Box	Panasonic	ECQ−U3A473MG
C3		Not Fitted			
C4	100 nF	300 VAC Polyester Film	Box	Panasonic	ECQ−U3A104MG
C5	4,700 pF	Ceramic 2000 V Y5U	Radial Disc	AVX	5SS472SBHCA
C6, C8	10 μF	50 V Electrolytic, 5 mm dia	Radial	Panasonic	EEU−EB1H100S
C7	1 nF	50 V Ceramic X7R	0603 SMD	Panasonic	ECJ−1VB1H102K
C9	470 pF	50 V Ceramic C0G, NPO	0603 SMD	Murata	GRM1885C1H471JA01D
C10	4.7 nF	250 VAC Y5U X1Y1 (LS = 10 mm)	Radial	Panasonic	CD16−E2GA472MYNS
C11, C12	1,500 μF	16 V Aluminum Electrolytic	Radial	United Chemi−Con	EKZE160ELL152MK20S
C13	100 nF	25 V Ceramic X7R	0603 SMD	Panasonic	ECJ−1VB1E104K
C14	1 μF	16 V Ceramic X7R	0603 SMD	TDK	C1608X7R1C105M080AC
C15	100 pF	50 V Ceramic NPO	1206 SMD	Kemet	C1206C101K5GACTU
C16	100 nF	100 V Ceramic X7R	1206 SMD	Panasonic	ECJ−3YB2A104K
D1, D2, D3, D4	MRA4007	Rectifier, 1000 V, 1 A	SMA	ON Semiconductor	MRA4007T3
D5	ES1M	Fast Rectifier 1 A, 1000 V	SMA	Micro Commercial	ES1M
D6	BAS21	250 V, 200 mA	SOT23	ON Semiconductor	BAS21LT1G
D7, D13	BAW56	70 V, 200 mA	SOT23	ON Semiconductor	BAW56LT1G
D8	BZX84C5V1	5.1 V ZENER	SOT23	ON Semiconductor	BZX84C5V1LT1G
D9	MMBZ5245	15 V ZENER	SOT23	ON Semiconductor	MMBZ5245BLT1
D10	NTSJ20100	Schottky, 100 V, 20 A	TO−220	ON Semiconductor	NTSJ20100CTG
D11	BZX84C5V6	5.6 V ZENER	SOT23	ON Semiconductor	BZX84C5V6LT1G
D12	BZX84C13	13 V ZENER	SOT23	ON Semiconductor	BZX84C13ET1G
F1	−	Slow Blow 1 A TE5 Series	Axial	Littelfuse	3691100044
J1, J2	−	Screw Connector (0.2″ Pitch)	Through Hole	Weidmuller	1716020000
L1	27 mH	Common Mode Choke	Through Hole	Wurth Midcom	7446620027
L2, L3	800 μH	Shielded Radial Inductor	Through Hole	Renco	RL−8054−3−821KR38−S
Q1, Q2, Q4, Q5	MMBTA06	NPN, 80 V, 500 mA	SOT23	ON Semiconductor	MMBTA06LT1G
Q3	SPD02N80	N-channel 800 V, 2 A	DPAK	Infineon	SPD02N80C3
R1	0 Ω	Wire Jumper	−	−	−
R2, R3	5K6	1/10 W	0603 SMD	Panasonic	ERJ−3GEYJ562V
R4, R5		Not Fitted			
R6, R7	47K	1/4 W	1206 SMD	Panasonic	ERJ−8GEYJ473V
R11, R15	100K	1/10 W	0603 SMD	Panasonic	ERJ−3EKF1003V
R12, R13	100K	1/4 W	1206 SMD	Panasonic	ERJ−8GEYJ104V
R9, R10	6K2	1/10 W	0603 SMD	Panasonic	ERJ−3EKF6201V
R14	4K7	1/10 W	0603 SMD	Panasonic	ERJ−3EKF4701V
R16	47K	1/10 W	0603 SMD	Panasonic	ERJ−3EKF4702V
R24	1K	1/10 W	0603 SMD	Panasonic	ERJ−3EKF1001V
R17, R18	100	1/10 W	0603 SMD	Panasonic	ERJ−3EKF1000V
R19	10	1/10 W	0603 SMD	Panasonic	ERJ−3EKF10R0V
R20	0.33	1 W	Axial	Yageo	FMP100JR−52−0R33
R21	22K	1/4 W	1206 SMD	Panasonic	ERJ−8GEYJ223V
R22, R23, R25	1K	1/10 W	0603 SMD	Panasonic	ERJ−3EKF1001V

Table 3. BILL OF MATERIALS (Changes to Demo Board Highlighted) (continued)

Designator	Value	Description	Footprint	Manufacturer	Part Number
R26	0	1/10 W	0603 SMD	Panasonic	ERJ−3GEY0R00V
R27	3K3	1/10 W	0603 SMD	Panasonic	ERJ−3EKF3300V
R28	160	1/10 W	0603 SMD	Panasonic	ERJ−3EKF1600V
R29	0.1	1/4 W	1206 SMD	Rohm Semi	MCR18EZHFLR100
R29A	0.1	1/4 W	1206 SMD	Rohm Semi	MCR18EZHFLR100
R30	24K	1/10 W	0603 SMD	Panasonic	ERJ−3EKF2402V
R31	6K2	1/4 W	1206 SMD	Panasonic	ERJ−8ENF6201V
R32	24K	1/10 W	0603 SMD	Panasonic	ERJ−3EKF2402V
RT1	PRF21BC	PTC 470 OHM 85C	0603 SMD	Murata	PRF18BE471QB1RB
RV1	V300LA4P	300 V 25 Joule (LS = 7 mm)	Radial	Littelfuse	V300LA4P
U1	NCL30000	Single Stage PFC LED Driver	SOIC8	ON Semiconductor	NCL30000DR2G
U2	PS2561L_1	80 V, 50 mA	SMT4	NEC Electronics	PS2561L−1
U3	LM2904	Dual Op Amp	SOIC8	ON Semiconductor	LM2904DR2G
U4	TL431A	Programmable Reference	SOIC8	ON Semiconductor	TL431ACDG
T1	XFMR	Transformer, EFD25, 18 W	EFD25	Wurth Midcom	750313431

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