

**PMP6024**  
**100-240VAC Input, 60W, 2-string, PWM Dimmable**  
**LED Driver Test Report**



July, 2014

# 100-240VAC Input, 60W, 2-string, PWM Dimmable LED Driver

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## 1 Introduction

This UCC28811 reference design presents the UCC28811 AC-DC controller and the LM3409HV DC-DC controller driving two strings of LEDs up to 700mA each in an isolated flyback plus buck configuration. The LED current is controlled by a PWM dimming pulse signal. The LED current can be dimmed to 1/1000 at 1% PWM dimming duty cycle. The features of UCC28811 include Transition Mode Control, Single Stage Power Factor Correction, Over Voltage Protection, Low Start Up Current.

## 2 Description

This reference design provides a high-brightness LED driver based on the configured as an isolated flyback converter plus two buck converters. The flyback converter provides an isolated 50V bus and a 15V bias voltage for secondary controllers. The flyback converter also achieves input power factor correction. The LED currents are regulated by two LM3409 based buck converters which convert 50V bus voltage to LED voltages. A PWM signal controls the LED current reference of the buck converters.

This reference design is designed to operate with an input voltage in the range of 100VAC to 240VAC. This design is set up for two strings of LEDs with current up to 700mA each. The typical LED stack voltage is 45V.

### 2.1 *Flyback Power Supply Description*

This UCC28811 based flyback converter operates at critical conduction mode. The UCC28811 PWM circuit is self-oscillating with the turn-on being governed by a transformer zero energy detector (TZE pin) and the turn-off being governed by the current sense comparator.

MOSFET Q1 provides the IC start up current. Once the output voltage rises, the bias voltage from the transformer aux winding (7-5) starts providing current for the IC. When this bias voltage is above 10.6V, it turns on Q5 to discharge the gate of Q1.

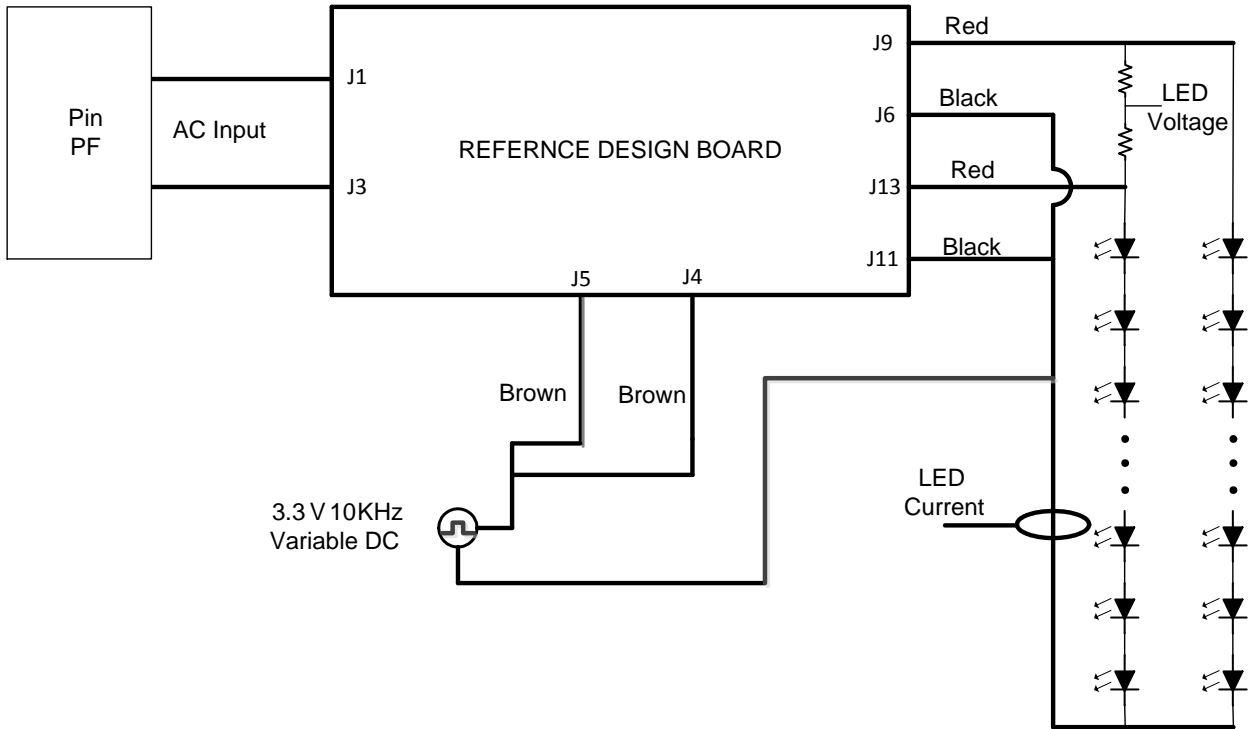
The power factor correction is achieved by sensing the rectified AC voltage on VINS pin through the resistor divider R20, R24, R45. The peak primary current of each switch cycle is proportional to the VINS pin voltage.

The over voltage protection (OVP) circuit consists of Q7 and U4. It pulls the IC VSENSE pin up when the voltage at the reference pin of shunt regulator U4 is over 1.24V.

### 2.2 *Buck Converter Description*

The second stage of this reference design includes two LM3409 based buck converters. LM3409 is a P channel MOSFET buck controller. So it is able to operate at close to 100% duty cycle. The LED current is set by the voltage at the IADJ pin. A 3.3V 10KHz PWM signal is applied at connectors J4 and J5. This PWM signal is filtered by RC filters R77 C68 and R87 C78 to generate a constant DC voltage at IADJ pins. This IADJ voltage is proportional to the PWM signal duty cycle.

### 2.3 Test Setup



### 3 Electrical Performance Specifications

**Table 1: UCC28811 Universal Input Dimmable 60W LED Driver Electrical Performance Specifications**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Input Characteristics</b>					
Voltage range	Normal operation	100	200	240	VAC
Maximum input current	At 200VAC 60Hz input voltage		0.4		A
<b>Output Characteristics</b>					
Output voltage, VOUT		30	45	48	V
Output load current, IOOUT	Input voltage = 200V 60Hz, Load = 45V LED	1300	1400	1500	mA
Output current regulation	Input voltage = 200V 60Hz, Load = 45V LED		< ±7		%
Output current ripple	Input voltage = 200V 60Hz, Load = 45V LED		<200		mApp
<b>Systems Characteristics</b>					
Switching frequency	Input voltage = 200V 60Hz, Load = 45V LED		120		kHz
Power Factor	Input voltage = 200V 60Hz, Load = 45V LED		0.97		
Efficiency	Input voltage = 200V 60Hz, Load = 45V LED		86		%

4 Schematic

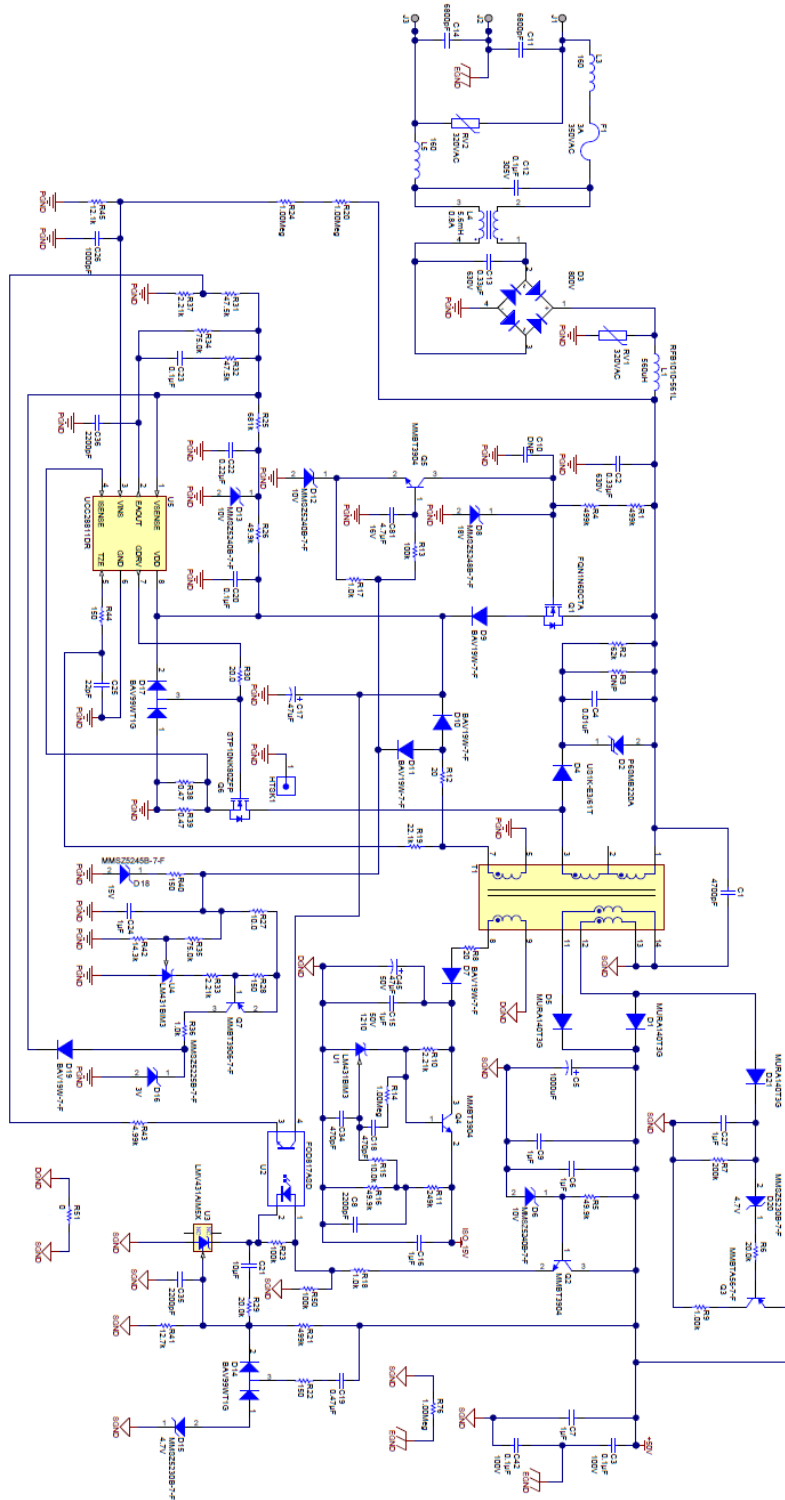


Figure 1: Universal Input Dimmable 60W LED Driver Schematic Page 1

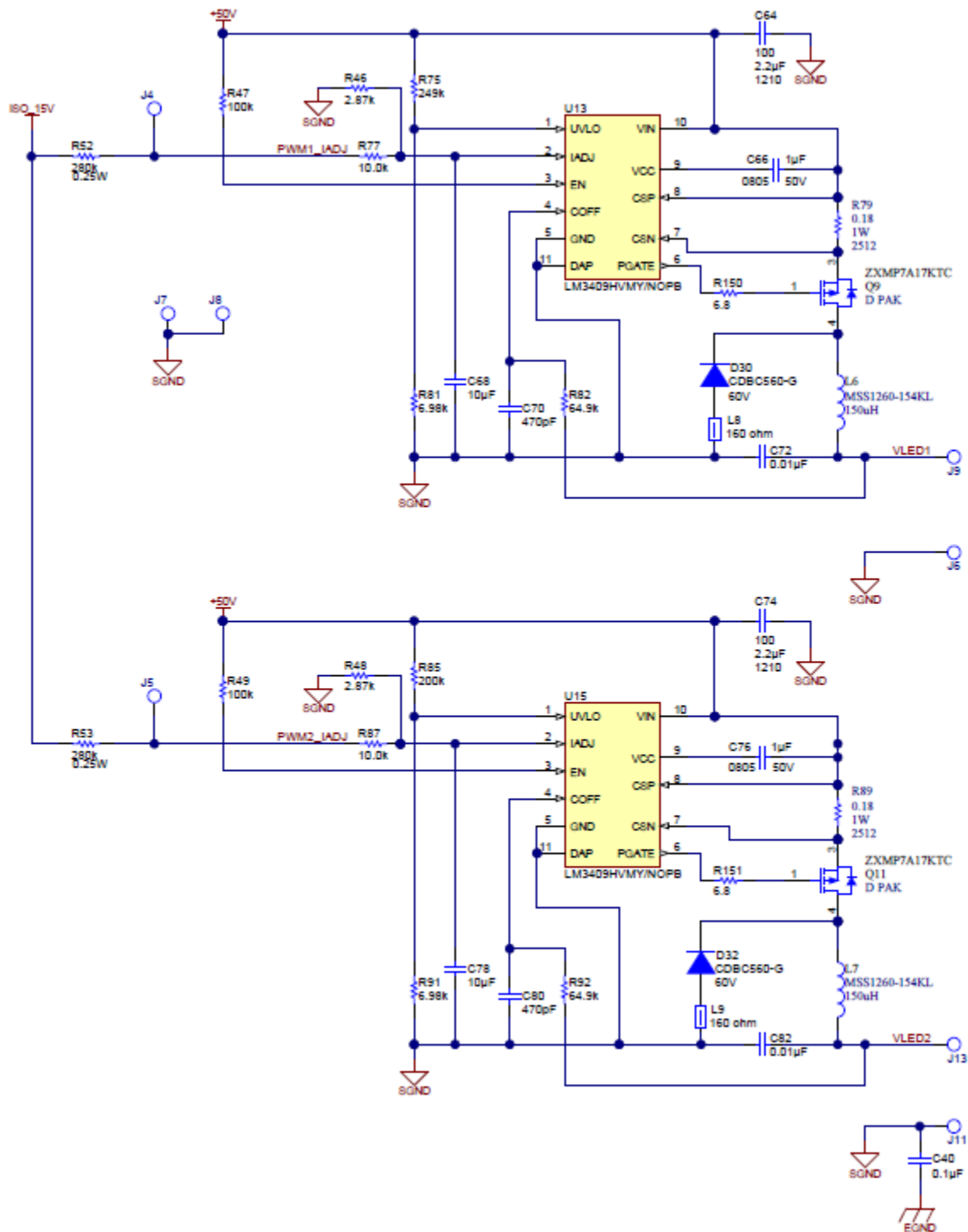


Figure 2: Universal Input Dimmable 60W LED Driver Schematic Page 2

## Performance Data and Typical Characteristic Curves

Figures 3 through 15 present typical performance curves for the UCC28811 Universal Input dimmable 60W LED Driver

### 4.1 Efficiency

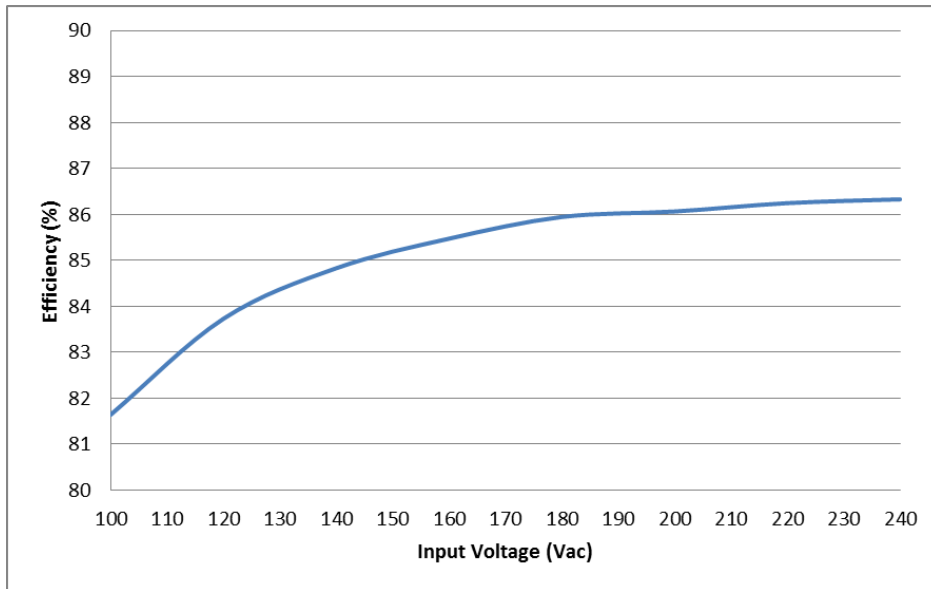


Figure 3: Efficiency

### 4.2 Line Regulation

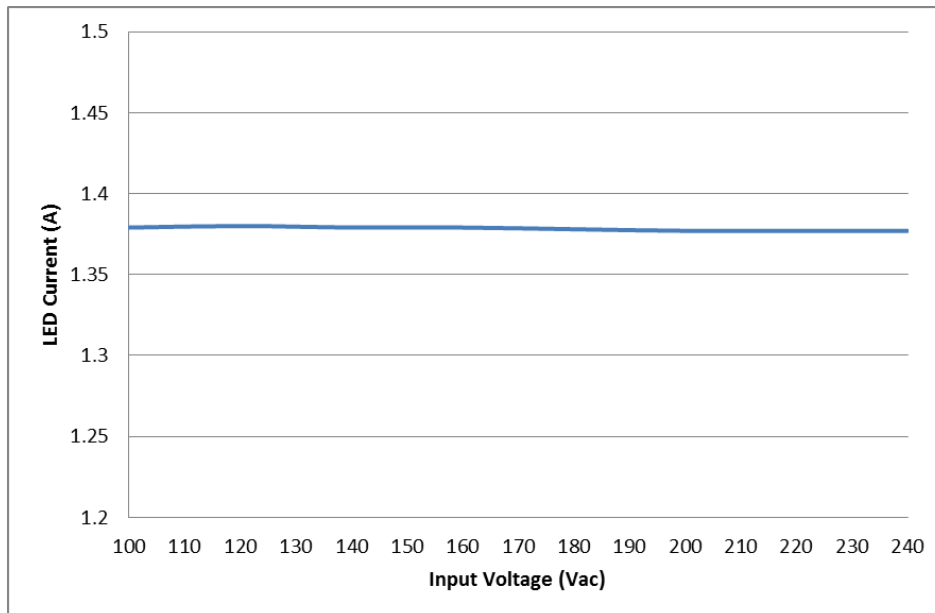
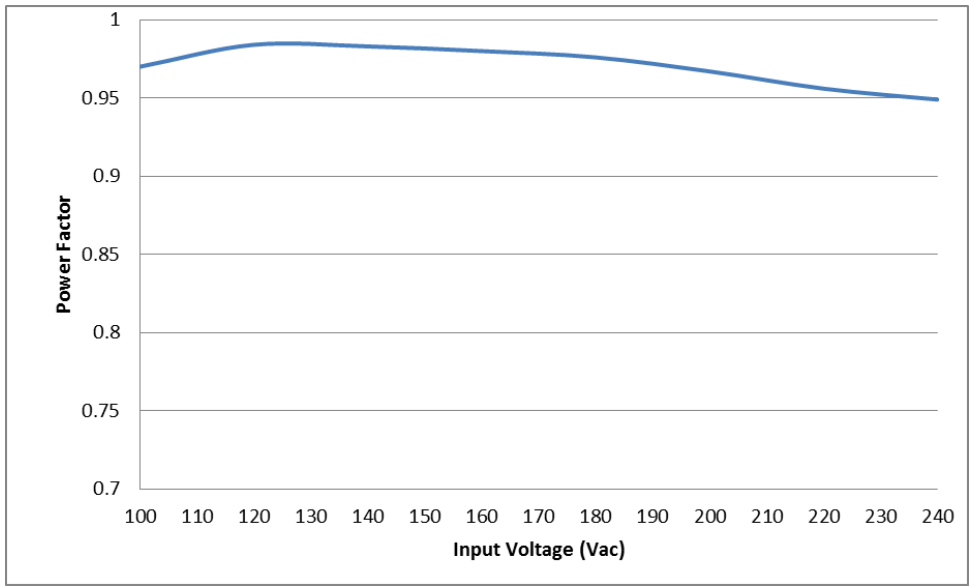


Figure 4: Line Regulation

### 4.3 Power Factor



**Figure 5: Power Factor**



#### 4.4 Dimming Curve

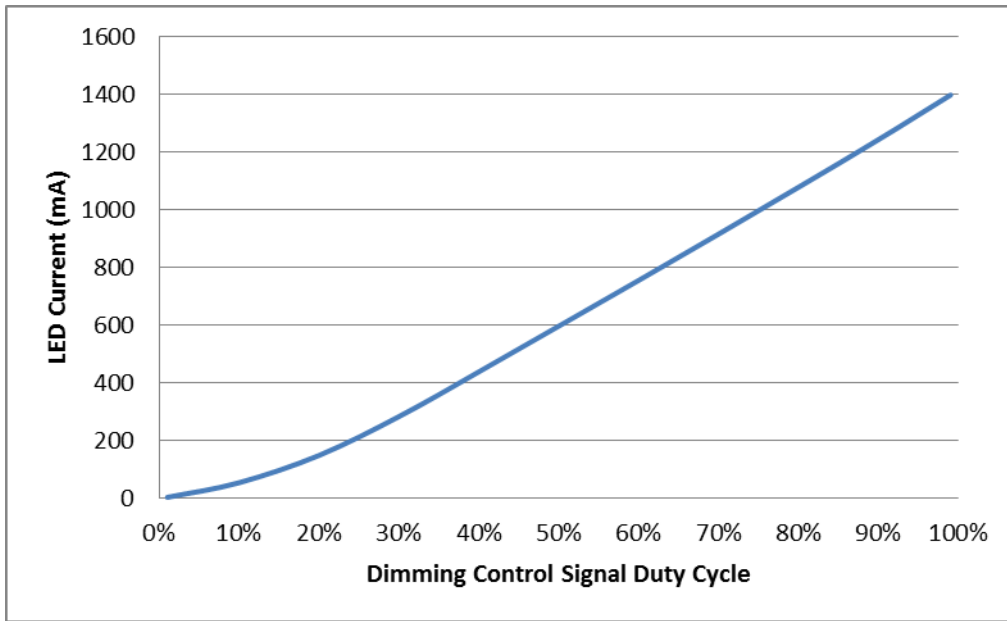


Figure 6: Dimming Performance 120V 60Hz

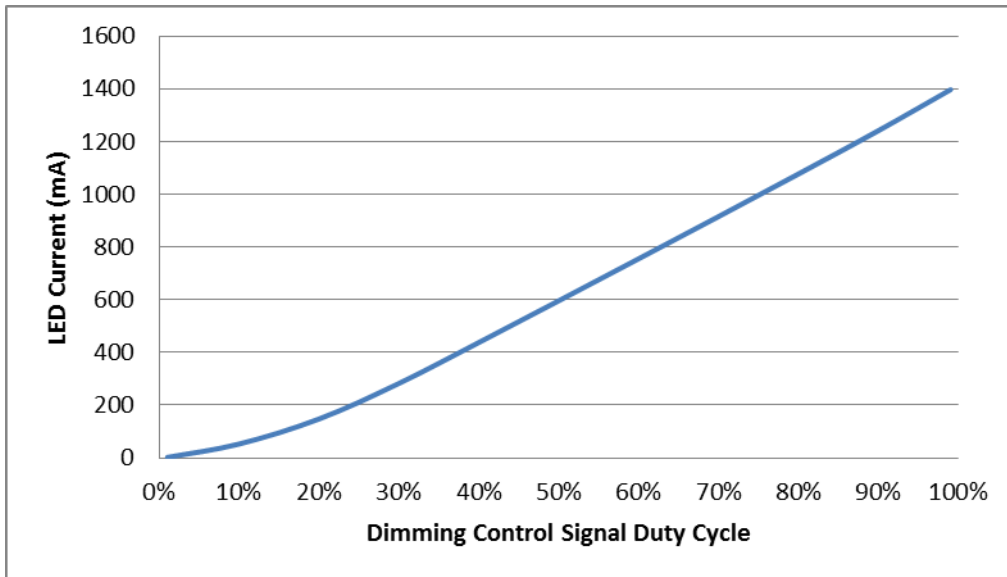


Figure 7: Dimming Performance 200V 60Hz

## 4.5 Input Current

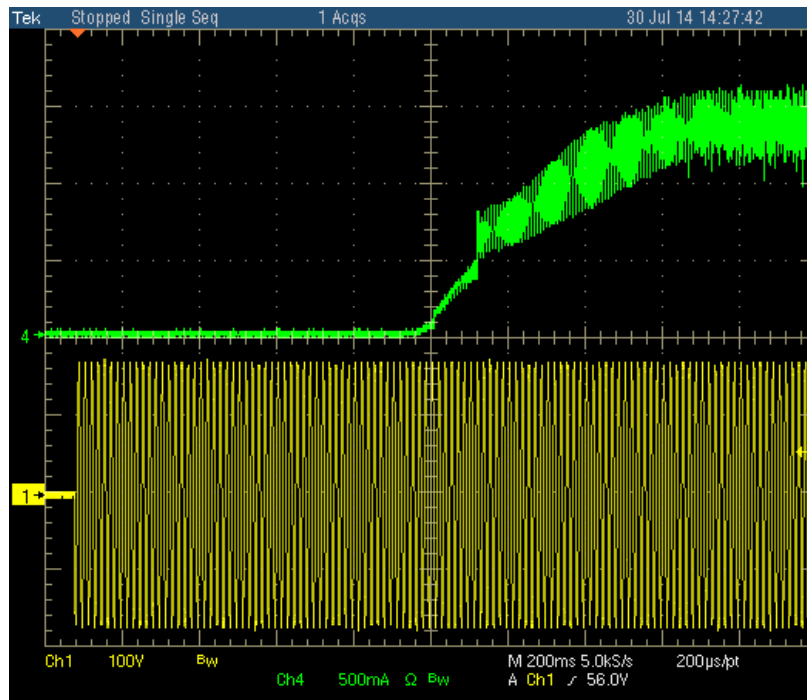


Figure 8: Start Up Waveforms at 120Vac 60Hz Ch1: AC Input Ch4: LED current

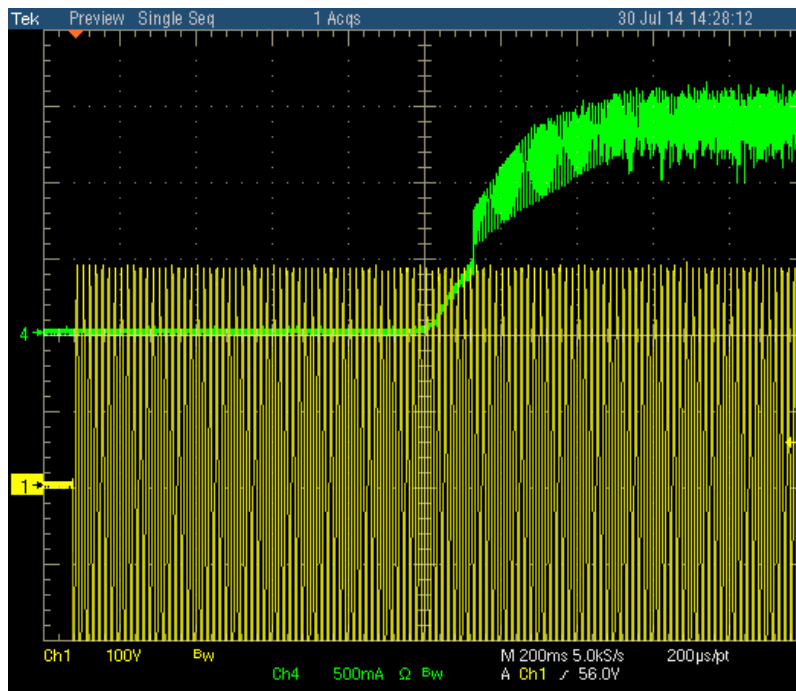


Figure 9: Start Up Waveforms at 200Vac 60Hz Ch1: AC Input Ch4: LED current

## 4.6 Input Current

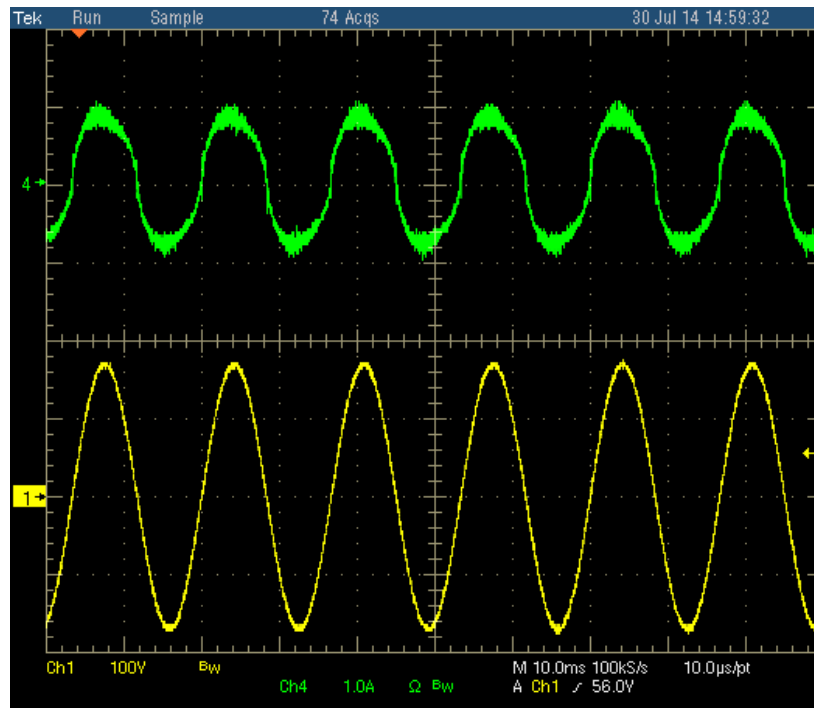


Figure 10: Input Current at 120V 60Hz Ch1: Input Voltage Ch4: Input Current

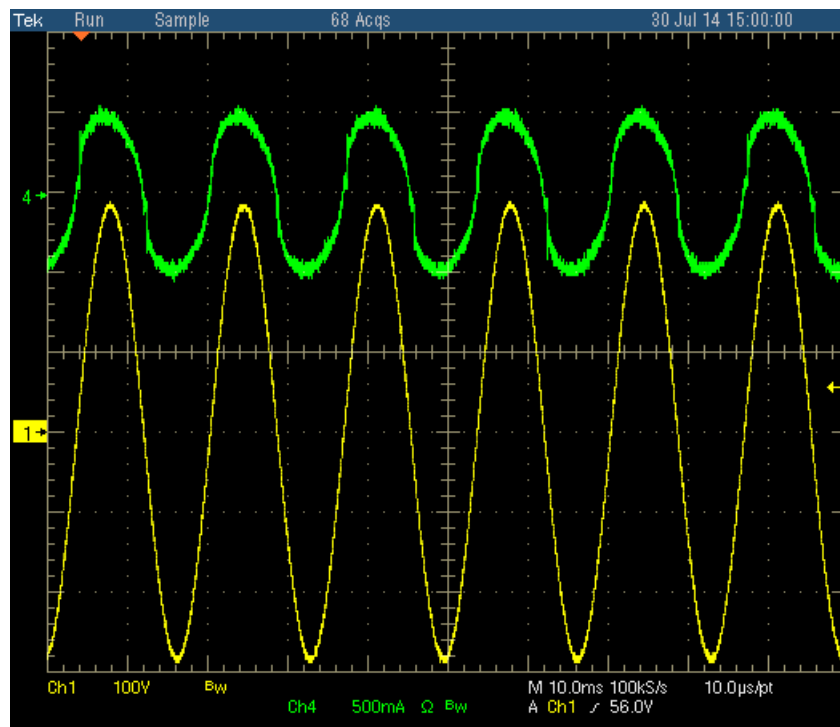


Figure 11: Input Current at 200V 60Hz Ch1: Input Voltage Ch4: Input Current

## 4.7 Switch Waveforms

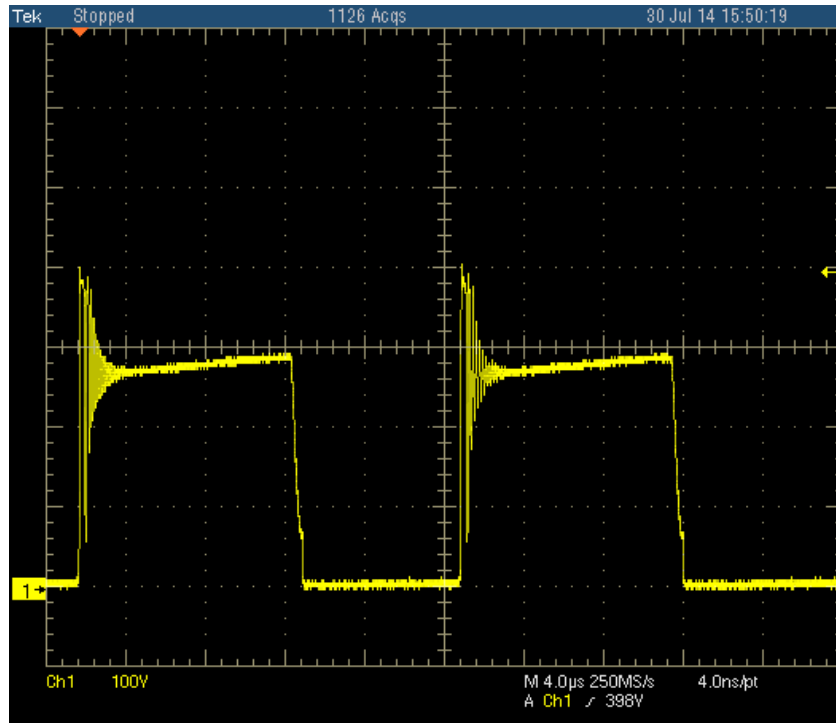


Figure 12: Switch Node at 120V 60Hz Ch1: MOSFET Q6 Drain

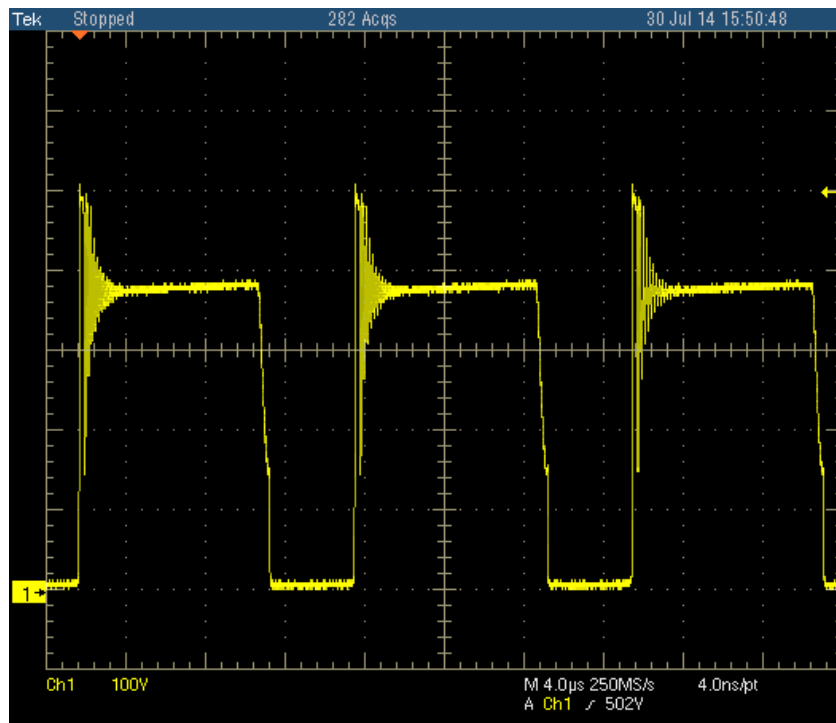
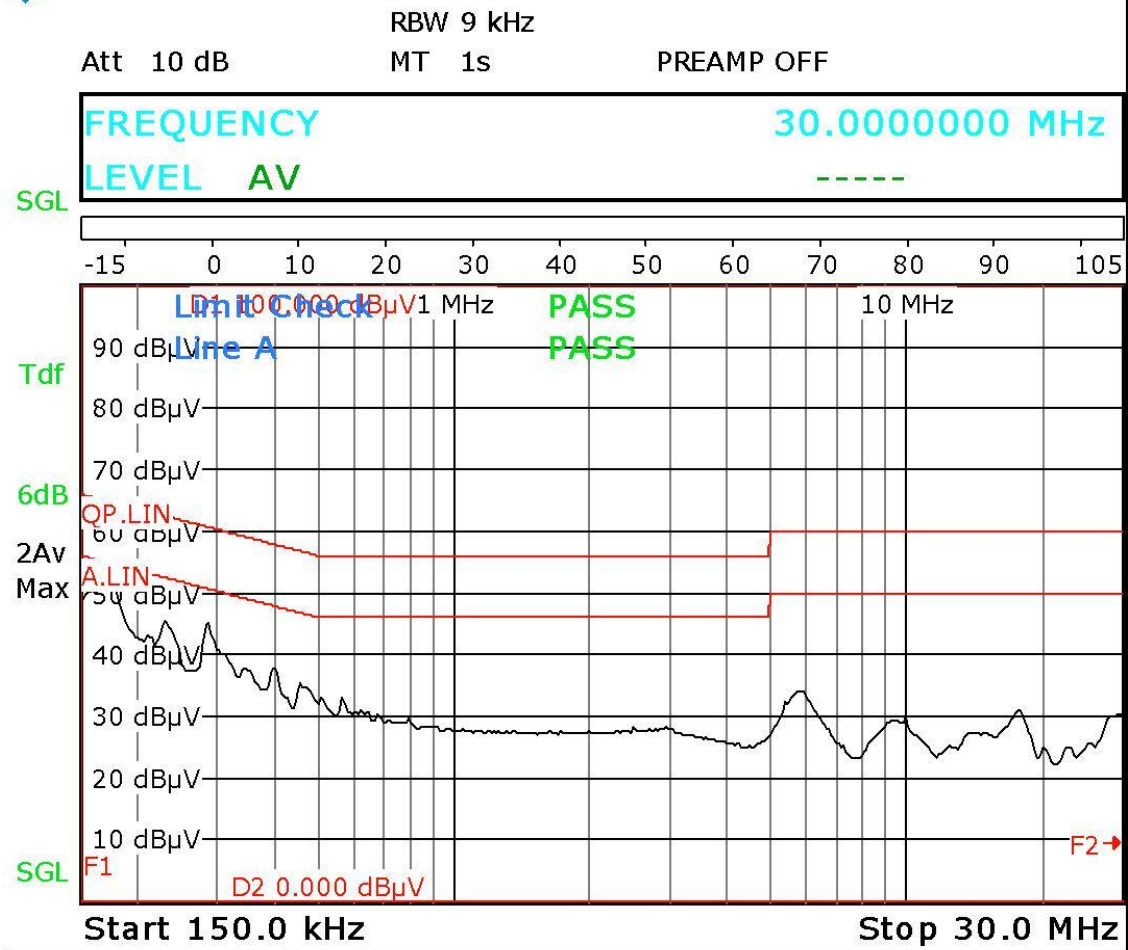


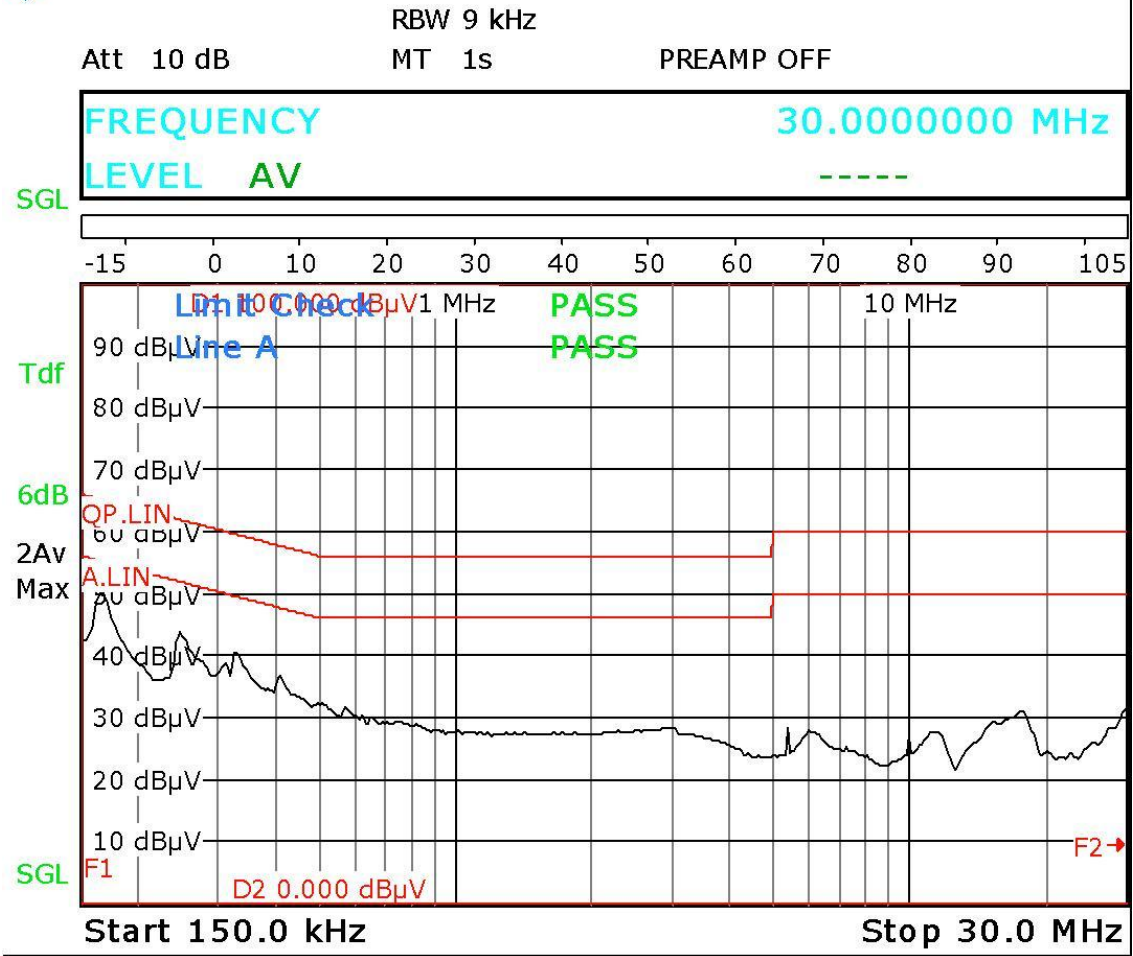
Figure 13: Switch Node at 200V 60Hz Ch1: MOSFET Q6 Drain

4.8 EMI Performance



Date: 29.JUL.2014 06:02:25

Figure 14: 120VAC Conducted EMI Average Scan



Date: 29.JUL.2014 05:47:07

Figure 15: 220VAC Conducted EMI Average Scan

## 5 UCC28811 Universal Input Dimmable 60W LED Driver Reference Design PCB layout

The following figures (Figure 16 through Figure 17) show the design of the printed circuit board.

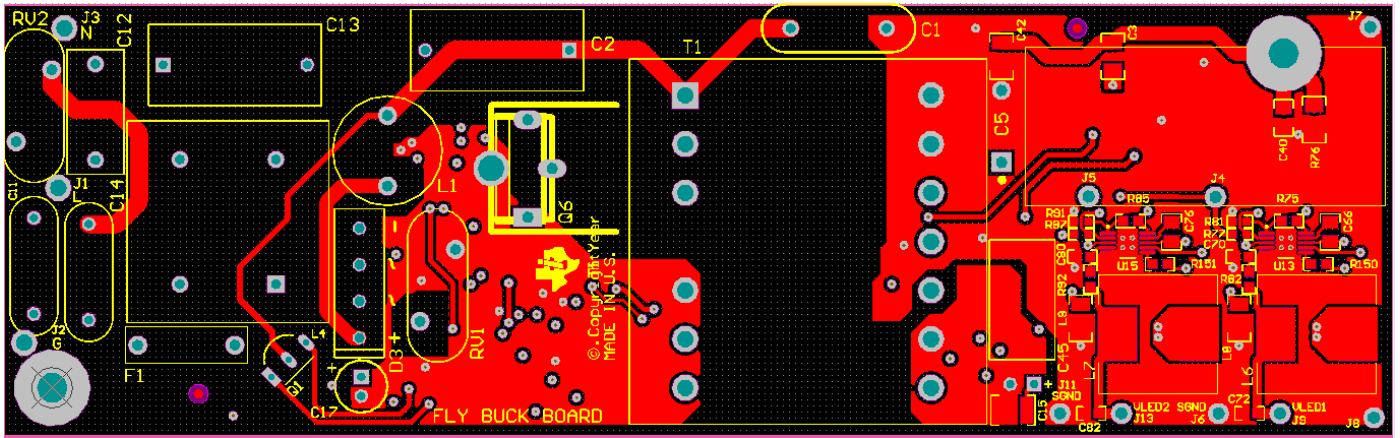


Figure 16: Top Layer and Top Overlay (Top view)

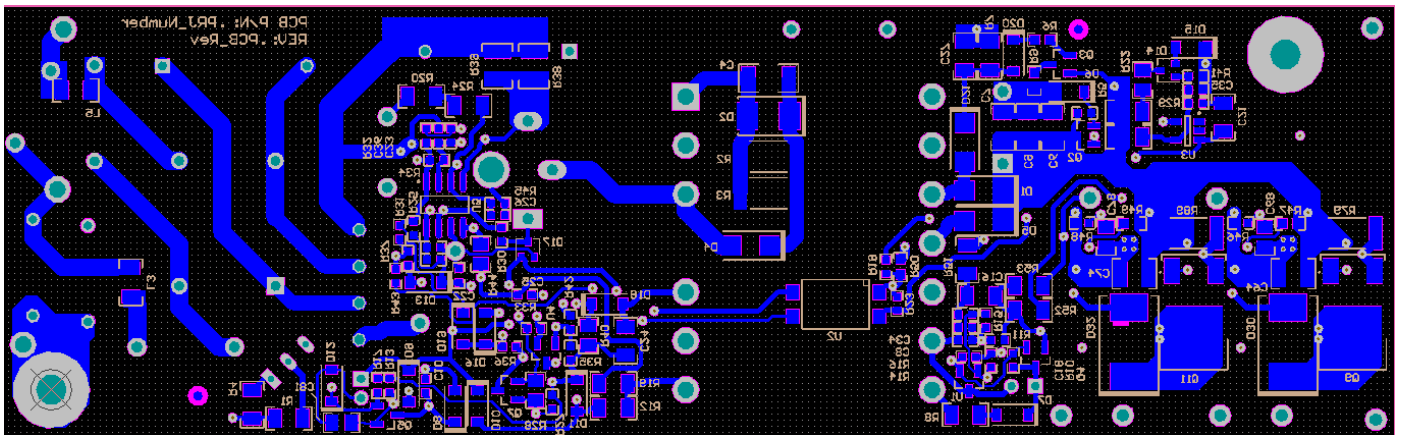


Figure 17: Bottom Layer and Bottom Overlay (Bottom view)

## 6 Bill of Materials

**Table 1: The components list of the Main Board according to the schematic shown in Figure 1**

Designator	Quantity	Value	Description	Package	PartNumber	Manufacturer
C6, C7, C9, C16, C24, C27	6	1uF	CAP, CERM, 1uF, 100V, +/-10%, X7R, 1206	1206	GRM31CR72A105KA01L	MuRata
C8, C35, C36	3	2200pF	CAP, CERM, 2200pF, 50V, +/-10%, X7R, 0603	0603	C0603C222K5RACTU	Kemet
C10	1	DNP	DNP	0603	DNP	MuRata
C11, C14	2	6800pF	CAP, Safety, 6800pF, 300VAC, Y5U, 20%, Radial, Disc	Radial, Disc	VY2682M59Y5US63V0	Vishay BC Components
C12	1	0.1uF	CAP, FILM, 0.1uF, 305VAC, Radial	Radial	B32921C3104M	EPCOS Inc
C15	1	1uF	CAP, CERM, 1uF, 50V, +/-10%, X7R, 1210	1210	GRM32RR71H105KA01L	MuRata
C17	1	47uF	CAP, Aluminum, 47uF, 25V, +/-20%, Radial	Radial	EEU-EB1E470S	Panasonic
C18, C34	2	470pF	CAP, CERM, 470pF, 100V, +/-5%, C0G/NP0, 0603	0603	GRM1885C2A471JA01D	MuRata
C19	1	0.47uF	CAP, CERM, 0.47uF, 100V, +/-10%, X7R, 1206	1206	GRM31MR72A474KA35L	MuRata
C20, C23	2	0.1uF	CAP, CERM, 0.1uF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H104KA93D	MuRata
C21	1	10uF	CAP, CERM, 10uF, 10V, +/-10%, X5R, 1206	1206	GRM31CR71A106KA01L	MuRata
C22	1	0.22uF	CAP, CERM, 0.22uF, 25V, +/-10%, X7R, 0603	0603	GRM188R71E224KA88D	MuRata
C25	1	22pF	CAP, CERM, 22pF, 100V, +/-5%, C0G/NP0, 0603	0603	GRM1885C2A220JA01D	MuRata
C26	1	1000pF	CAP, CERM, 1000pF, 100V, +/-10%, X7R, 0603	0603	GRM188R72A102KA01D	MuRata
C40	1	0.1uF	CAP, CERM, 0.1uF, 100V, +/-10%, X7R, 0805	0805	C0805C104K1RACTU	Kemet
C45	1	47uF	CAP, Alum, 47uF, 50V, +/-20%, Radial	Radial, Can	UPW1H470MED	Nichicon
C64, C74	2	2.2uF	CAP, CERM, 2.2uF, 100V, +/-10%, X7R, 1210	1210	HMK325B7225KN-T	Taiyo Yuden
C66, C76	2	1uF	CAP, CERM, 1uF, 50V, +/-10%, X7R, 0805	0805	GRM21BR71H105KA12L	MuRata
C68, C78	2	10uF	CAP, CERM, 10uF, 16V, +/-10%, X5R, 0805	0805	GRM21BR61C106KE15L	MuRata
C70, C80	2	470pF	CAP, CERM, 470pF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H471KA01D	MuRata
C72, C82	2	0.01uF	CAP, CERM, 0.01uF, 50V, +/-10%, X7R, 0603	0603	GRM188R71H103KA01D	MuRata
C81	1	4.7uF	CAP, CERM, 4.7uF, 16V, +/-10%, X5R, 0805	0805 (2012 Metric)	C2012X5R1C475K125AC	TDK Corporation
D1, D5, D21	3	400V	Diode, Ultrafas, 400V, 2A, SMA	SMA	MURA140T3G	ON Semiconductor
D2	1	220V	Diode, TVS, Uni, 600W, 220V, Unidirection, 5%, SMB	SMB	P6SMB220A	Littelfuse Inc
D3	1	800V	Diode, Switching-Bridge, 800V, 2A, SIP	SIP TH	2KBP08M-E4/51	Vishay Semi
D4	1	800V	Diode, Ultrafast, 800V, 1A, SMA	SMA	US1K-E3/61T	Vishay Semi
D6, D12, D13	3	10V	Diode, Zener, 10V, 500mW, SOD-123	SOD-123	MMSZ5240B-7-F	Diodes Inc.
D7, D9, D10, D11, D19	5	100V	Diode, Fast, 100V, 200mA, SOD-123	SOD-123	BAV19W-7-F	Diodes Inc
D8	1	18V	Diode, Zener, 18V, 500mW, SOD-123	SOD-123	MMSZ5248B-7-F	Diodes Inc.
D14, D17	2	0.63V	Diode, P-N, 70V, 0.2A, SOT-323	SOT-323	BAV99WT1G	Fairchild Semi



D15, D20	2	4.7V	Diode, Zener, 4.7V, 500mW, SOD-123	SOD-123	MMSZ5230B-7-F	Diodes Inc.
D16	1	3V	Diode, Zener, 3V, 500mW, SOD-123	SOD-123	MMSZ5225B-7-F	Diodes Inc.
D18	1	15V	Diode, Zener, 15V, 500mW, SOD-123	SOD-123	MMSZ5245B-7-F	Diodes Inc.
D30, D32	2	750mV @ 5A	DIODE SCHOTTKY 60V 5A DO214AB	DO-214AB, SMC	CDBC560-G	Comchip Technology
F1	1	3A	Fuse, 3A, 350VAC, Board Mount	Board Mount	0447003.YXP	Littelfuse Inc
FID1, FID2, FID3, FID4	4		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
H2, H3	2		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H6, H7	2		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
HTSK1	1		HTSK, Aavid P/N 7141DG, TO-220 Vert, PCB mount	Htsk_7141DG	7141DG	Aavid Thermalloy
J4, J5, J6, J7, J8, J9, J11, J13	8		18 GA WIRE HOLE	NA	NA	NA
L1	1	560uH	Inductor, 560uH, 1.05A, Radial	Radial	RFB1010-561L	Coilcraft
L3, L5	2	160	Inductor, Ferrite EMI Chip, 160 Ohm @ 100KHz, 6A, 18m ohm, SMT	1206	HI1206T161R-10	Laird
L4	1	5.6mH	Coupled Inductor, 5.6mH, 0.8A, 245m ohm, +/-15%, Through Hole	Horizontal EH Choke	EH20-0.8-02-5M6	Schaffner EMC Inc
L6, L7	2	150uH	Technology, Imax, DCR	MSS1260	MSS1260-154KL	CoilCraft
L8, L9	2	160 ohm	6A Ferrite Bead, 160 ohm @ 100MHz, SMD	1206	HI1206T161R-10	Steward
Q1	1	600V	MOSFET, N-CH, 600V, 300mA, TO-92	TO-92	FQN1N60CTA	Fairchild Semi
Q2, Q4, Q5	3	0.2V	Transistor, NPN, 40V, 0.2A, SOT-23	SOT-23	MMBT3904	Fairchild Semi
Q3	1	Value	Transistor, PNP, 80V, SOT23	TO-236-3, SC-59, SOT-23-3	MMBTA56-7-F	Diodes Inc
Q6	1	800V	MOSFET, N-CH, 800V, 9A, TO-220FP	TO-220FP	STP10NK80ZFP	STMicroelectronics
Q7	1	0.25V	Transistor, PNP, 40V, 0.2A, SOT-23	SOT-23	MMBT3906-7-F	Diodes Inc.
Q9, Q11	2		MOSFET P-CH 70V 5.7A D PAK	D PAK	ZXMP7A17KTC	Diodes/Zetex
R1, R4, R21	3	499k	RES, 499k ohm, 1%, 0.25W, 1206	1206	CRCW1206499KFKEA	Vishay-Dale
R2	1	62k	RES, 62k ohm, 5%, 1W, 2512	2512	CRCW251262K0JNEG	Vishay Dale
R3	1	DNP	DNP	2512	DNP	Vishay Dale
R5, R16, R26	3	49.9k	RES, 49.9k ohm, 1%, 0.1W, 0603	0603	CRCW060349K9FKEA	Vishay-Dale
R6, R29	2	20.0k	RES, 20.0k ohm, 1%, 0.1W, 0603	0603	CRCW060320K0FKEA	Vishay-Dale
R7	1	200k	RES, 200k ohm, 1%, 0.25W, 1206	1206	CRCW1206200KFKEA	Vishay-Dale
R8, R12	2	20	RES, 20 ohm, 5%, 0.25W, 1206	1206	CRCW120620R0JNEA	Vishay-Dale
R9	1	1.00k	RES, 1.00k ohm, 1%, 0.1W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R10, R33, R37	3	2.21k	RES, 2.21k ohm, 1%, 0.1W, 0603	0603	CRCW06032K21FKEA	Vishay-Dale
R11, R75	2	249k	RES, 249k ohm, 1%, 0.1W, 0603	0603	CRCW0603249KFKEA	Vishay-Dale
R13, R23, R47, R49, R50	5	100k	RES, 100k ohm, 1%, 0.1W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R14	1	1.00Meg	RES, 1.00Meg ohm, 1%, 0.1W, 0603	0603	CRCW06031M00FKEA	Vishay-Dale
R15, R77, R87	3	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R17, R18, R36	3	1.0k	RES, 1.0k ohm, 5%, 0.1W, 0603	0603	CRCW06031K00JNEA	Vishay-Dale

R19	1	22.1k	RES, 22.1k ohm, 1%, 0.25W, 1206	1206	CRCW120622K1FKEA	Vishay-Dale
R20, R24, R76	3	1.00Meg	RES, 1.00Meg ohm, 1%, 0.25W, 1206	1206	CRCW12061M00FKEA	Vishay-Dale
R22, R28, R40, R44	4	150	RES, 150 ohm, 1%, 0.125W, 0805	0805	CRCW0805150RFKEA	Vishay-Dale
R25	1	681k	RES, 681k ohm, 1%, 0.1W, 0603	0603	CRCW0603681KFKEA	Vishay-Dale
R27	1	10.0	RES, 10.0 ohm, 1%, 0.1W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale
R30	1	20.0	RES, 20.0 ohm, 1%, 0.1W, 0603	0603	CRCW060320R0FKEA	Vishay-Dale
R31, R32	2	47.5k	RES, 47.5k ohm, 1%, 0.1W, 0603	0603	CRCW060347K5FKEA	Vishay-Dale
R34, R35	2	75.0k	RES, 75.0k ohm, 1%, 0.1W, 0603	0603	CRCW060375K0FKEA	Vishay-Dale
R38, R39	2	0.47	RES, 0.47 ohm, 1%, 0.5W, 1210	1210	MCR25JZHFLR470	Rohm
R41	1	12.7k	RES, 12.7k ohm, 1%, 0.1W, 0603	0603	CRCW060312K7FKEA	Vishay-Dale
R42	1	14.3k	RES, 14.3 k, 1%, 0.1 W, 0603	0603	CRCW060314K3FKEA	Vishay-Dale
R43	1	4.99k	RES, 4.99k ohm, 1%, 0.1W, 0603	0603	CRCW06034K99FKEA	Vishay-Dale
R45	1	12.1k	RES, 12.1k ohm, 1%, 0.1W, 0603	0603	CRCW060312K1FKEA	Vishay-Dale
R46, R48	2	2.87k	RES, 2.87 k, 1%, 0.1 W, 0603	0603	CRCW06032K87FKEA	Vishay-Dale
R51	1	0	RES, 0 ohm, 5%, 0.25W, 1206	1206	CRCW12060000Z0EA	Vishay-Dale
R52, R53	2	280k	RES, 280k ohm, 1%, 0.25W, 1206	1206	CRCW1206280KFKEA	Vishay-Dale
R79, R89	2	0.18	RES .18 OHM 1W 5% 2512 SMD	2512	ERJ-1TRSJR18U	Panasonic
R81, R91	2	6.98k	RES, 6.98k ohm, 1%, 0.1W, 0603	0603	CRCW06036K98FKEA	Vishay-Dale
R82, R92	2	64.9k	RES, 64.9k ohm, 1%, 0.1W, 0603	0603	CRCW060364K9FKEA	Vishay-Dale
R85	1	200k	RES, 200k ohm, 1%, 0.1W, 0603	0603	CRCW0603200KFKEA	Vishay-Dale
R150, R151	2	6.8	RES, 6.8 ohm, 5%, 0.1W, 0603	0603	CRCW06036R80JNEA	Vishay-Dale
RV1	1	320VAC	Varistor, 320VAC, 420VDC, 84J, 14mm, Disc	Disc 14mm	S14K320E2K1	EPCOS Inc
RV2	1	320VAC	Varistor, 320VAC, 420VDC, 150J, 14mm, Disc	Disc 14mm	S14K320E2K1	EPCOS Inc
T1	1	450uH	Xfmr, ETD Core, 450uH, 64 Np, 26 Ns, 8 Na1, 10 Na2, ETD29/16/10	ETD29 14 Pin Vertical		Würth/Midcom
U1, U4	2		Adjustable Precision Zener Shunt Regulator, 3-pin SOT-23	MF03A	LM431BIM3	Texas Instruments
U2	1		Optoisolator, Phototrans Out, 4-SMD	4-SMD	FOD817ASD	Fairchild Semi
U3	1		Low-Voltage (1.24V) Adjustable Precision Shunt Regulators, 5-pin SOT-23	MF05A	LMV431AIM5X	Texas Instruments
U5	1		LED Lighting Power Controller, -40 to +105 degC, 8-pin SOIC (D), Green (RoHS & no Sb/Br)	D0008A	UCC28811DR	Texas Instruments
U13, U15	2		PFET Buck Controller for High Power LED Drives, 10-pin eMSOP, Pb-Free	MUC10A	LM3409HVMY/NOPB	Texas Instruments
C6, C7, C9, C16, C24, C27	6	1uF	CAP, CERM, 1uF, 100V, +/-10%, X7R, 1206	1206	GRM31CR72A105KA01L	MuRata

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