PMP6023
TPS92210
Universal Input 0-10V Dimmable 25W LED Driver Reference Design

May, 2014

Texas Instruments

Universal Input 0-10V Dimmable 25W LED Driver

1 Introduction

This TPS92210 reference design presents the TPS92210 AC-DC controller driving a 50V string of LEDs at 500mA in an isolated flyback configuration with an isolated 0-10V dimmer interface. The 0-10V dimming ratio is approximately 9:1. This power supply is power factor corrected and has power factor up to 0.99. The TPS92210 is a natural power factor correction LED driver with advanced energy features to provide high efficiency control for LED lighting applications. The features of TPS92210 include Constant On-Time Enables Single Stage Power Factor Correction, Cascoded MOSFET for Fast and Easy Startup, Fully Integrated Current Control without Sense Resistor, Transformer Zero Energy Detection Enables Valley Switching Operation.

2 Description

This reference design provides a high-brightness LED driver based on the configured as an isolated flyback converter with nature power factor correction. This design is dimmable by 0-10V dimmers with a dimming ratio of 9:1. It is designed to operate with an input voltage in the range of 100VAC to 264VAC. This design is set up for a 500mA LED current with LED stack voltage range from 45 V to 55 V.

2.1 Flyback Power Supply Description

The TPS92210 has two control modes. They are constant-on time control and peak-current mode control. This design uses peak-current mode control to ensure proper operation over a wide range of input voltage and 9:1 LED current dimming range. At full load, the converter is operating in the Frequency Modulation mode with a switching frequency around 120KHz.

In order for the converter to operate with a relatively constant switching frequency over the input voltage range, the switching on time needs to be adjusted according to the input voltage. This on time adjustment is achieved by injecting a current to the OTM resistor R19 through PNP transistor Q4. The injection current is controlled by the Q4 base voltage which is the divided average input voltage. At low line, the Q4 base voltage is low which increases the injection current and leads to longer on time. At high line, the Q4 base voltage is low which decreases the injection current and leads to shorter on time.

At low dimming level, the converter goes from the Frequency Modulation (FM) mode to the Amplitude Modulation (AM) mode. In AM mode, the peak primary current is programmed by the PCL resistor R19. This peak current needs to be set just above the actual peak current during full load operation to ensure smooth transition from FM mode to AM mode.

2.2 0-10V Dimmer Interface Daughter Board Description

The 0-10V dimmer interface circuit is located on the daughter board. It has a separated ground which is isolated from both primary and secondary grounds of the flyback power supply. It is powered by a 24V bias supply from the transformer winding (9-10). The dimming interface circuit takes the 0-10V dimming signal from the dimmer and compares it to a sawtooth waveform generated by a Programmable Unijunction Transistor (PUT) based oscillator. The comparator output, which is a square wave, drives an opto coupler. The duty cycle of the square wave is proportional to the 0-10V dimming signal. The opto coupler transfers this square wave signal to the flyback power supply secondary side. It is averaged by a RC filter to generate the LED current reference voltage for the power supply secondary control.

The 0-10V dimmer interface daughter board also provides a 1.5 mA current source to power the dimmer.

2.3 Features

2.3.1 Connector Description

This section describes the connectors of the reference design board.

2.3.1.1 J5

This connector is for the AC input to the board. Use the screw down terminal to connect Line and Neutral to the circuit.

2.3.1.2 J3 & J4

Connect J3 to the LED anode and J4 to the LED cathode.

2.3.1.3 TP1, TP2, TP3, TP4 on the daughter board

TP1 is internally connected to the 24V bias supply

Connect TP2 to the 0-10V dimmer output negative

Connect TP3 to the 0-10V dimmer output positive

Connect TP4 to the 0-10V dimmer supply (For most dimmers this is the same as output positive)

3 Electrical Performance Specifications

Table 1: TPS92210 Universal Input 0-10V dimmable LED Driver Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range	Normal operation	100	120/230	264	VAC
Maximum input current	At 120VAC 60Hz input voltage		0.05		A
Output Characteristics					
Output voltage, VOUT		45	50	55	V
Output load current, IOUT	Input voltage = 120V 60Hz, Load = 50V LED Input voltage = 230V 50Hz, Load = 50V LED	480	500	520	mA
Output current regulation	Input voltage = 120V 60Hz, Load = 50V LED Input voltage = 230V 50Hz, Load = 50V LED		< ±4		%
Output current ripple	Input voltage = 120V 60Hz, Load = 50V LED Input voltage = 230V 50Hz, Load = 50V LED		<170 <200		mApp
Systems Characteristics					
Switching frequency	Input voltage = 120V 60Hz, Load = 50V LED Input voltage = 230V 50Hz, Load = 50V LED		120 120		kHz
Power Factor	Input voltage = 120V 60Hz, Load = 50V LED Input voltage = 230V 50Hz, Load = 50V LED		0.99 0.96		
Efficiency	Input voltage = 120V 60Hz, Load = 50V LED Input voltage = 230V 50Hz, Load = 50V LED		86 86		%

4 Schematic

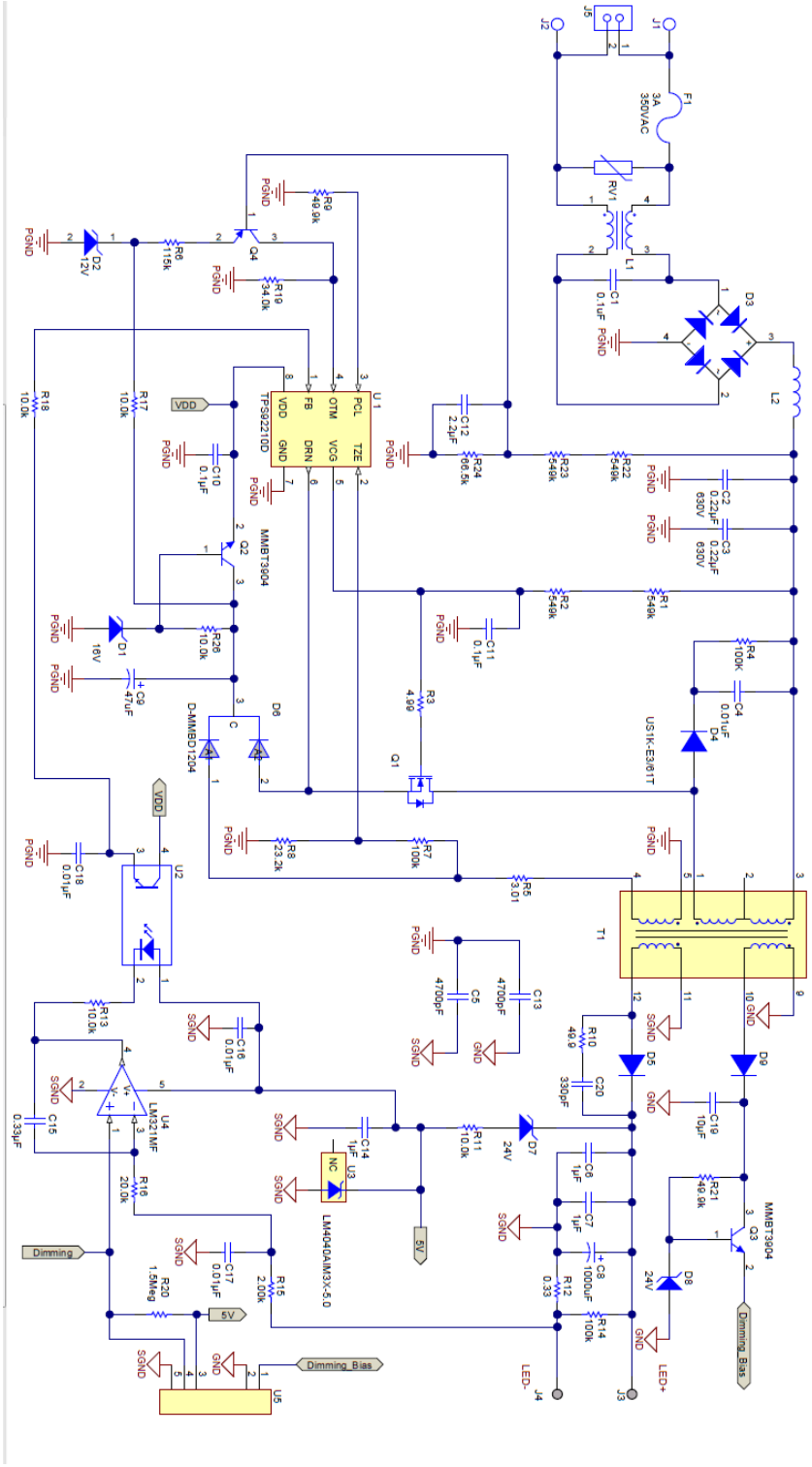

Figure 1: TPS92210 Universal Input 0-10V Dimmable LED Driver Main Board Schematic

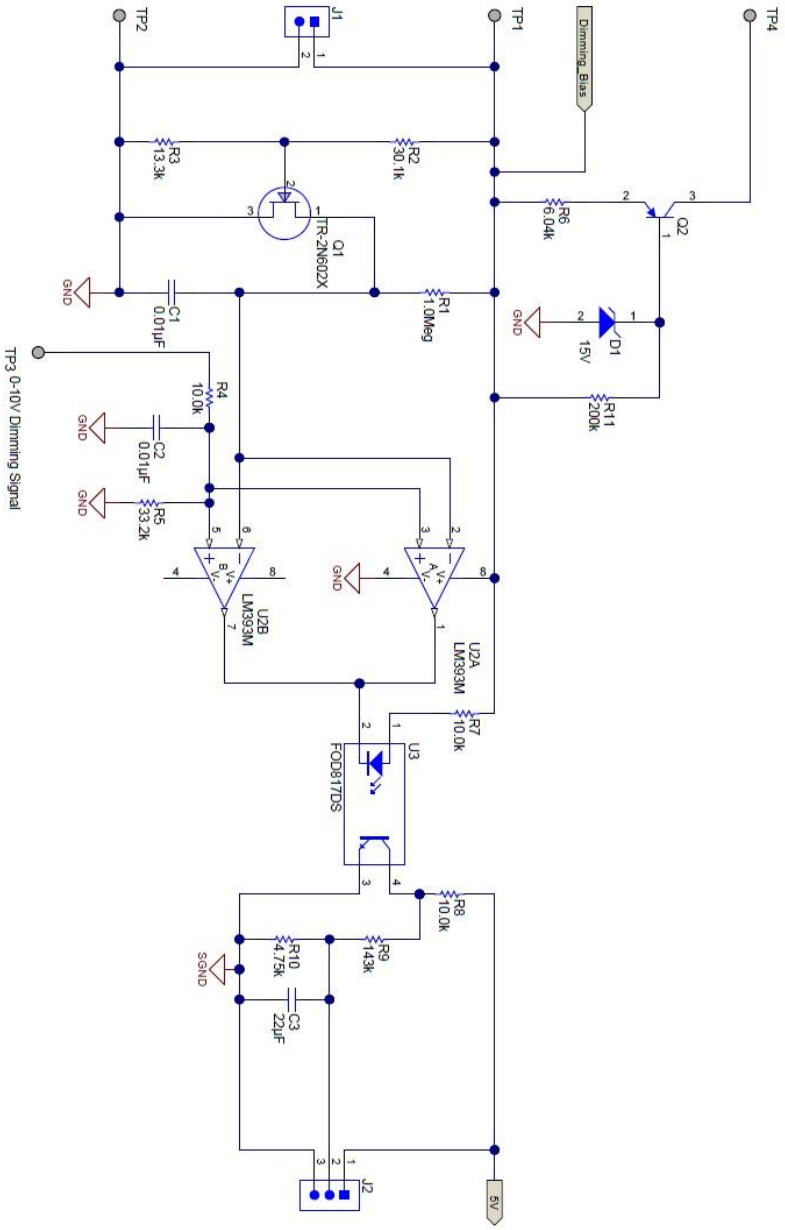

Figure 2: TPS92210 Universal Input 0-10V Dimmable LED Driver Daughter Board Schematic

Performance Data and Typical Characteristic Curves

Figures 3 through 13 present typical performance curves for TPS92210 Universal Input 0-10 V dimmable LED Driver

4.1 Efficiency

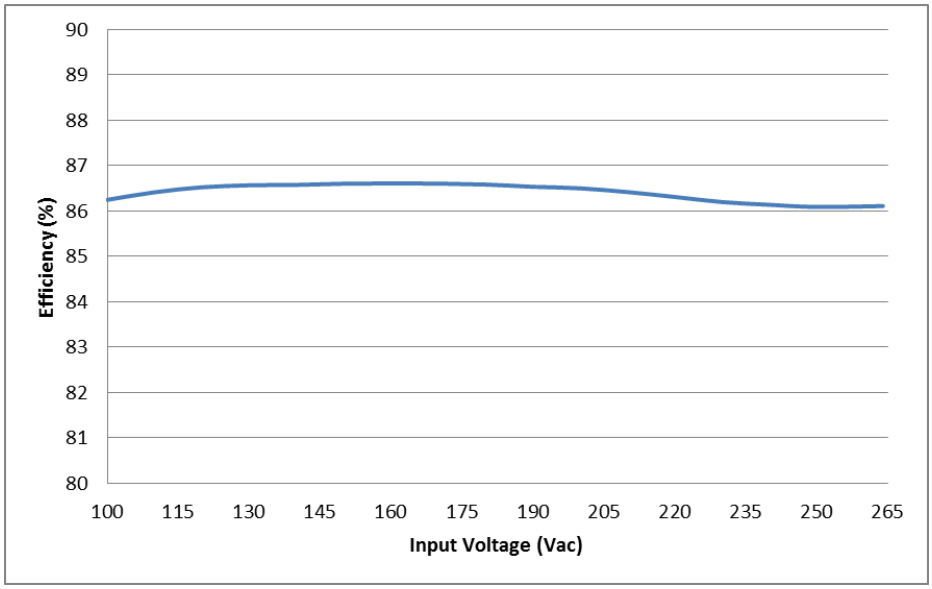

Figure 3: Efficiency

4.2 Line Regulation

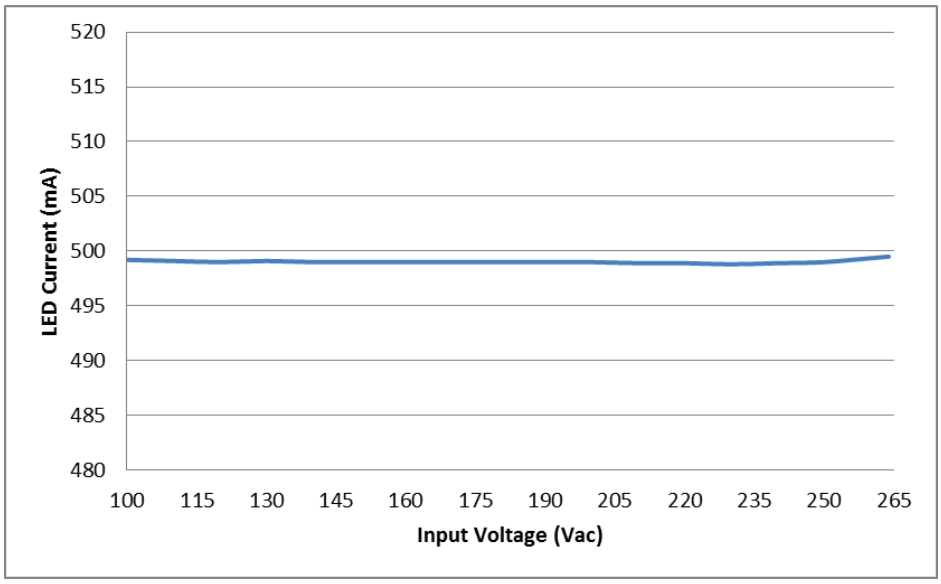

Figure 4: Line Regulation

4.3 Power Factor

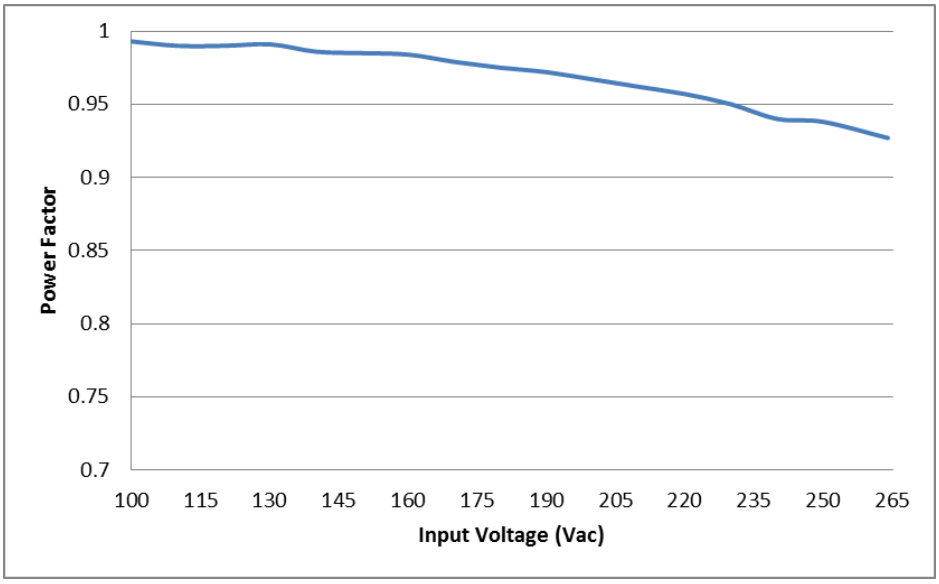

Figure 5: Power Factor 60Hz

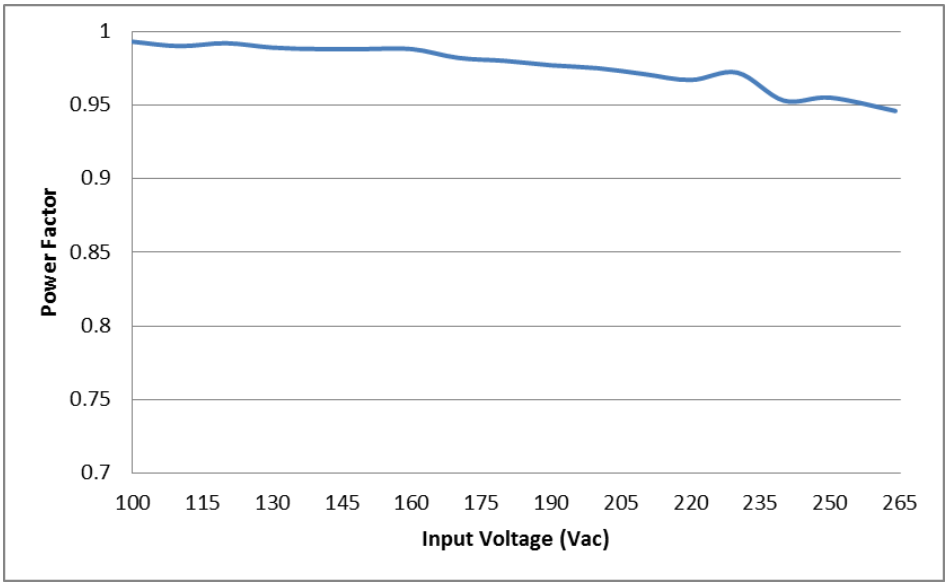

Figure 6: Power Factor 50Hz

4.4 Dimming Curve

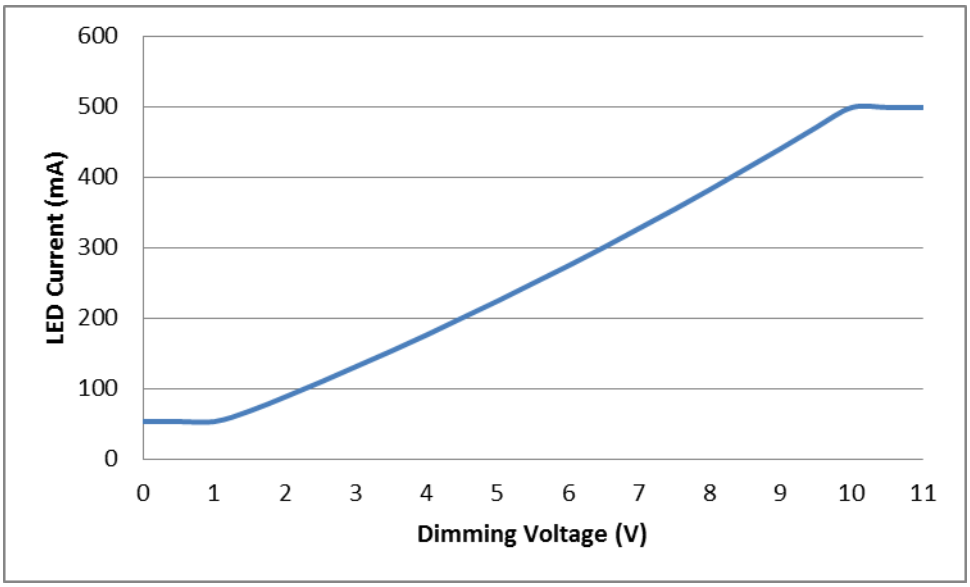

Figure 7: LED Current vs. Dimming Voltage

4.5 Start Up

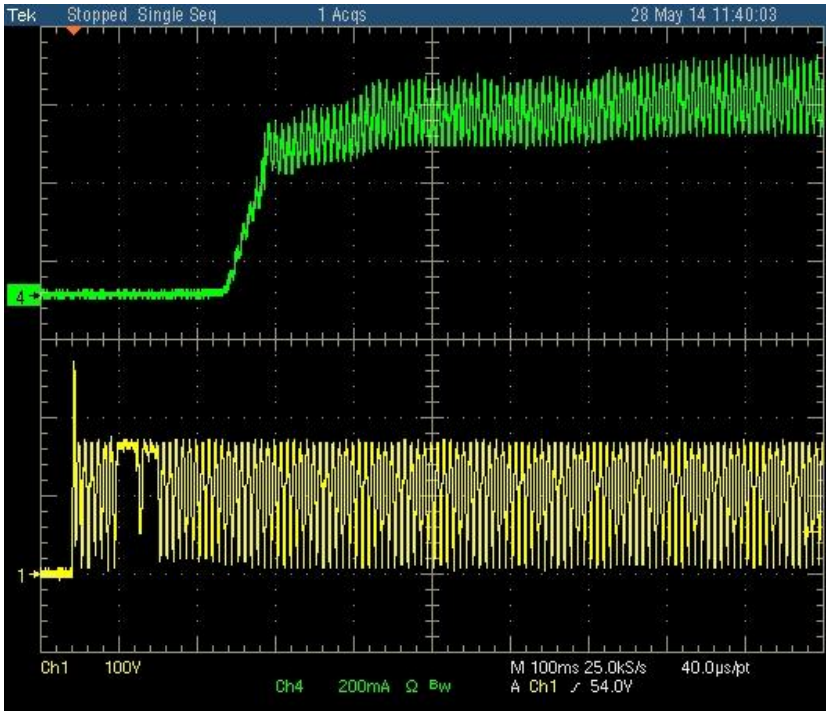

Figure 8: Start Up Waveforms at 120Vac 60Hz Ch1: Rectified AC Input Ch4: LED current

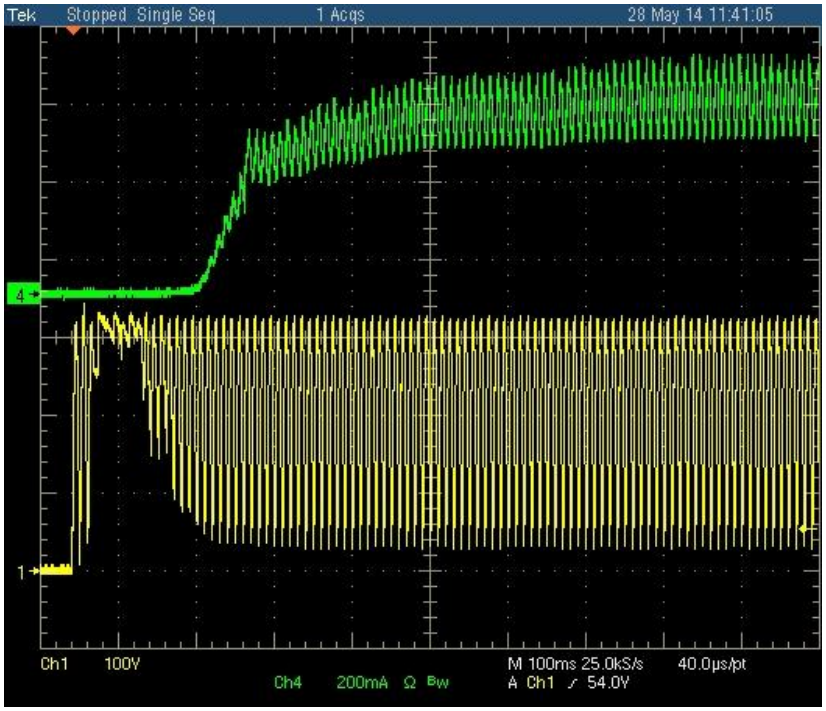

Figure 9: Start Up Waveforms at 230Vac 50Hz Ch1: Rectified AC Input Ch4: LED current

4.6 Input Current

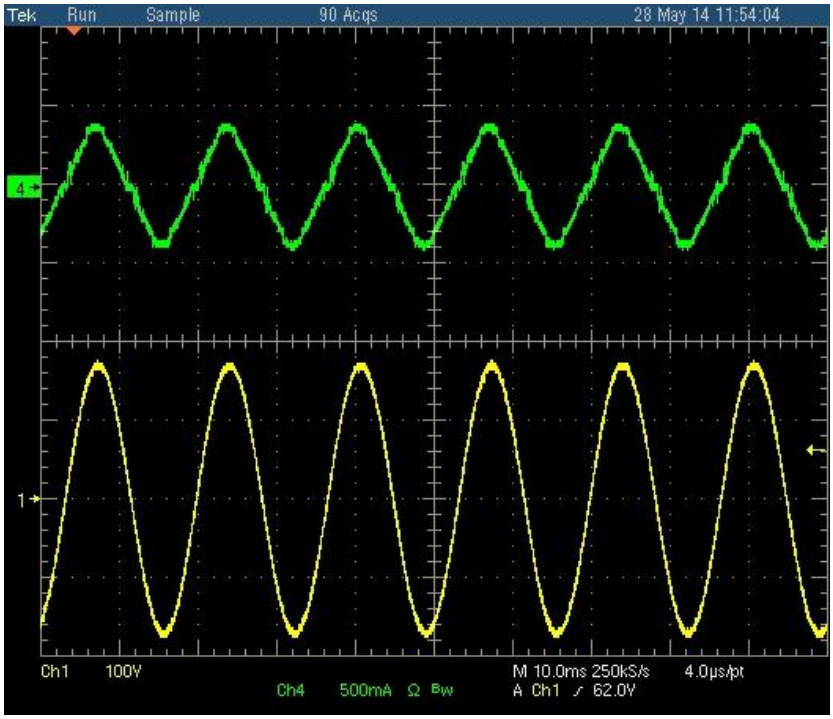

Figure 10: Input Current at 120V 60Hz Ch1: Input Voltage Ch4: Input Current

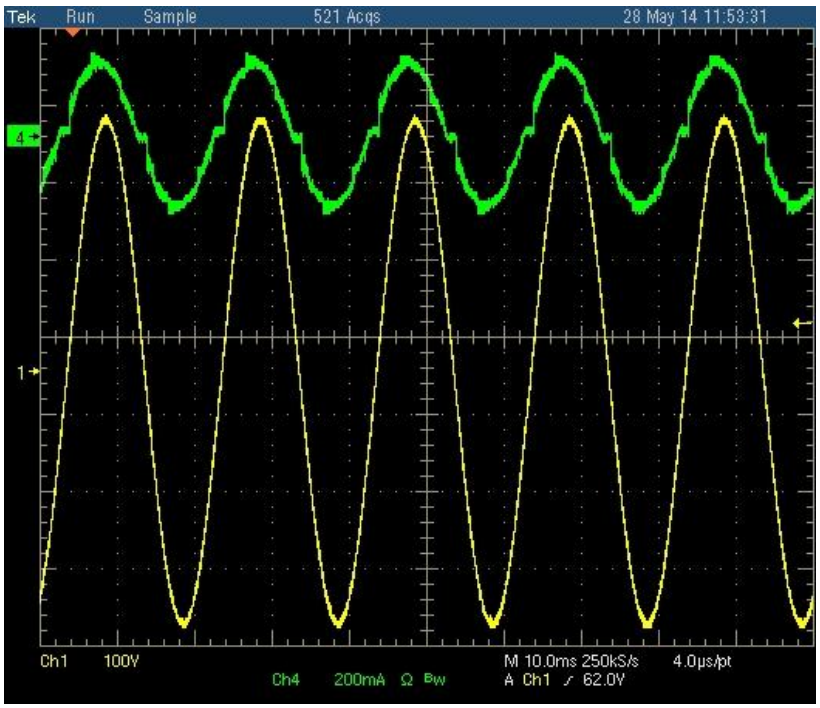

Figure 11: Input Current at 230V 50Hz Ch1: Input Voltage Ch4: Input Current

4.7 Switch Waveforms

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

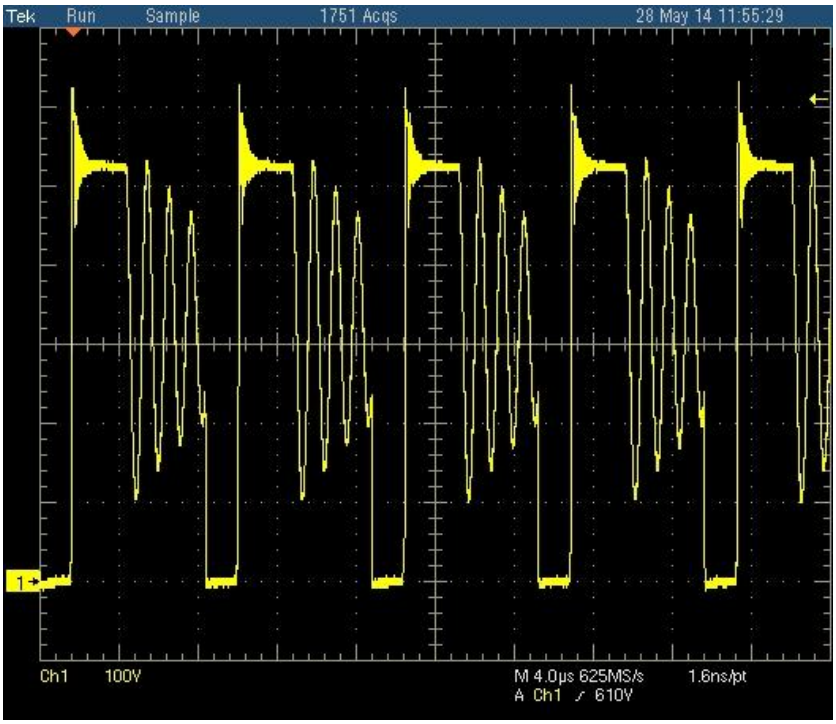

Figure 13: Switch Node at 230V 50Hz Ch1: MOSFET Q6 Drain

4.8 EMI Performance

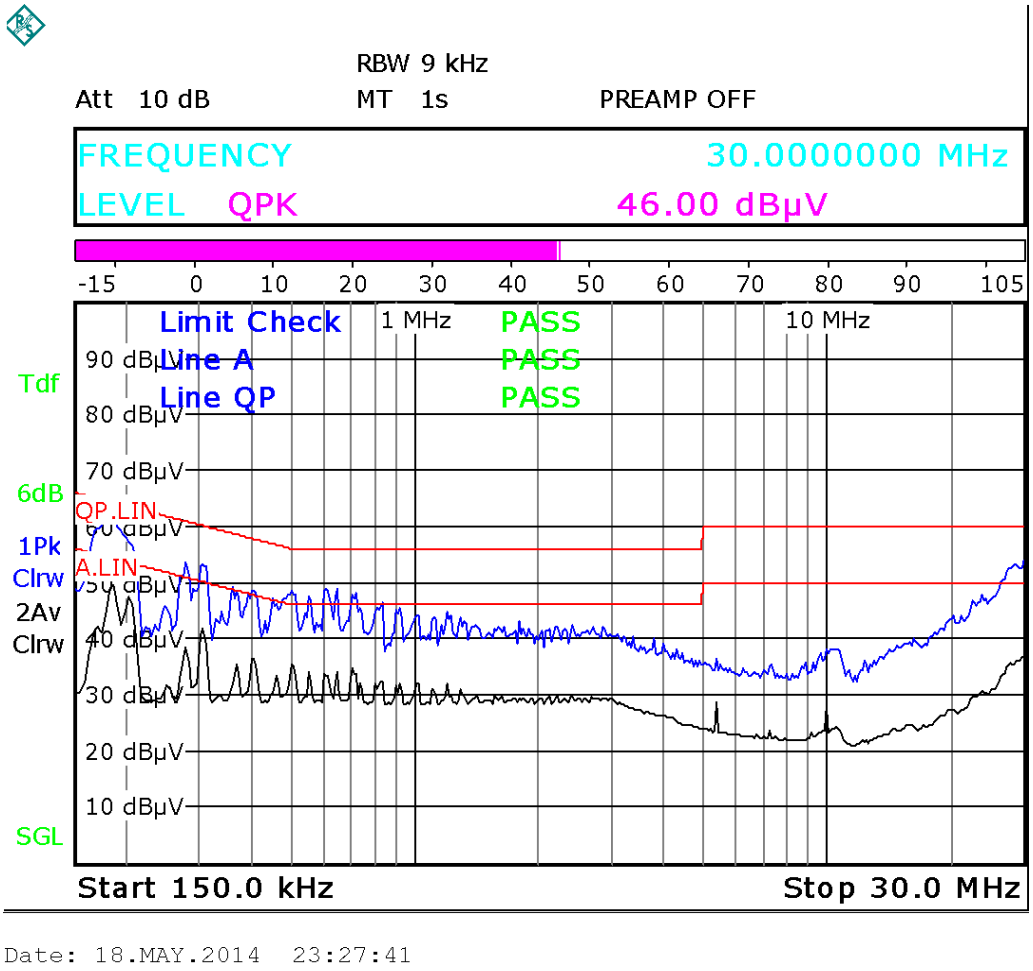

Figure 14: 120VAC Conducted EMI Scan

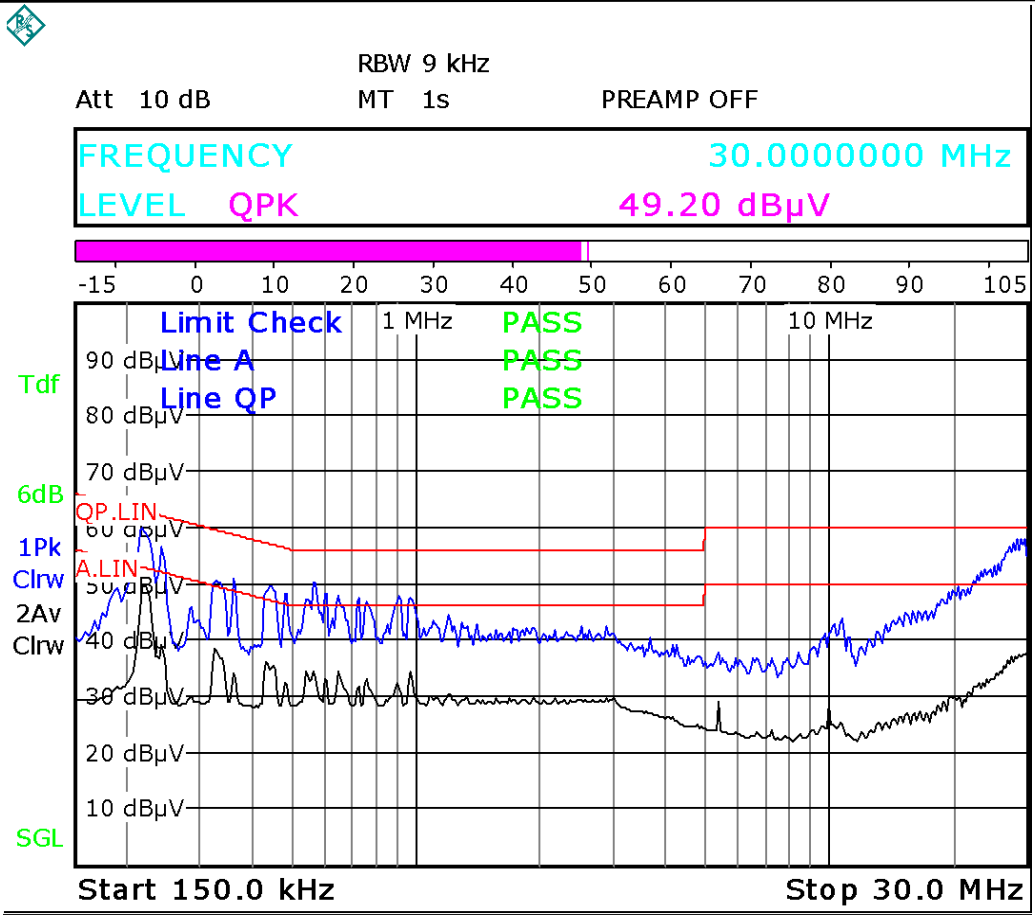

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Figure 15: 230VAC Conducted EMI Scan

5 TPS92210 Universal Input 0-10V Dimmable LED Driver Reference Design PCB layout

The following figures (Figure 16 through Figure 19) show the design of the printed circuit board.

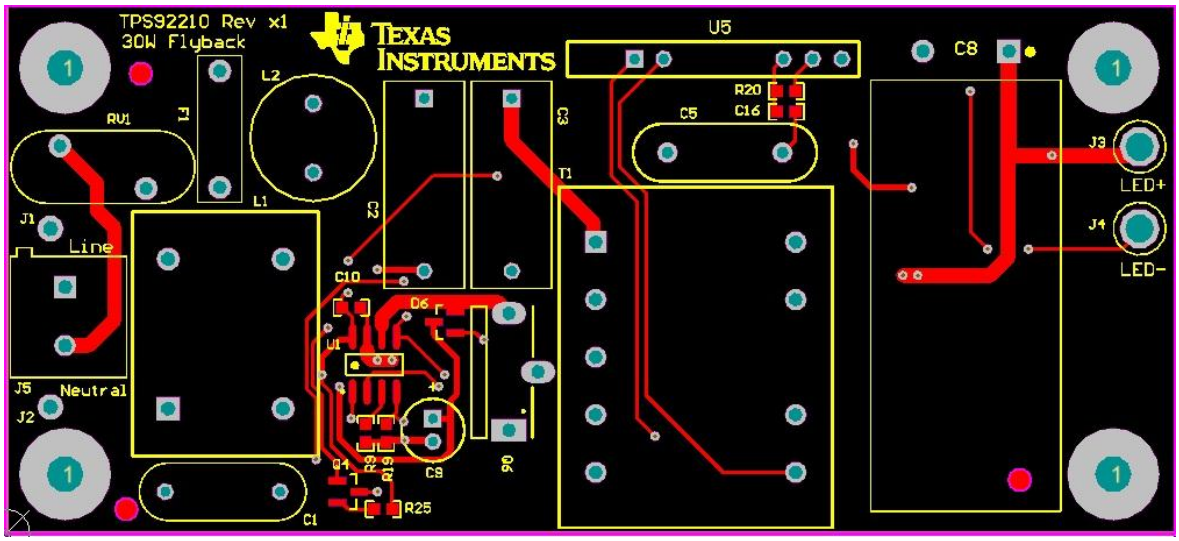

Figure 16: Top Layer and Top Overlay Main Board (Top view)

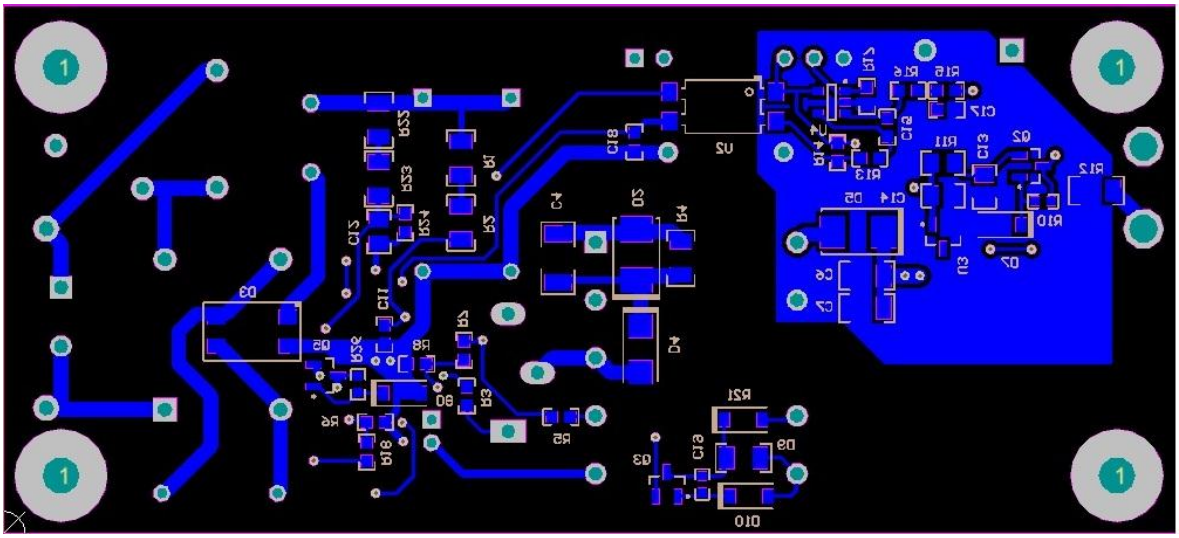

Figure 17: Bottom Layer and Bottom Overlay Main Board (Bottom view)

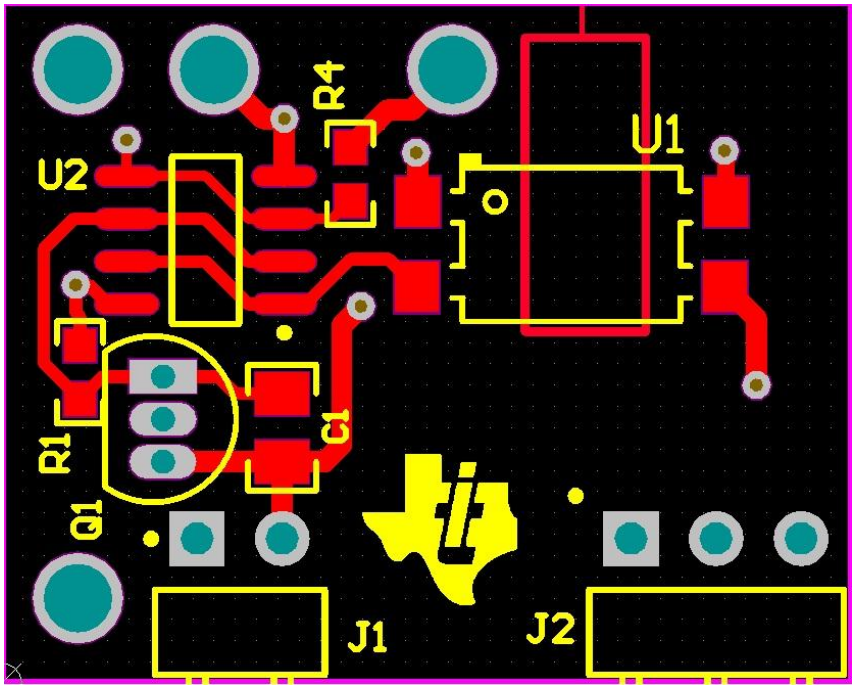

Figure 18: Top Layer and Top Overlay Daughter Board (Top view)

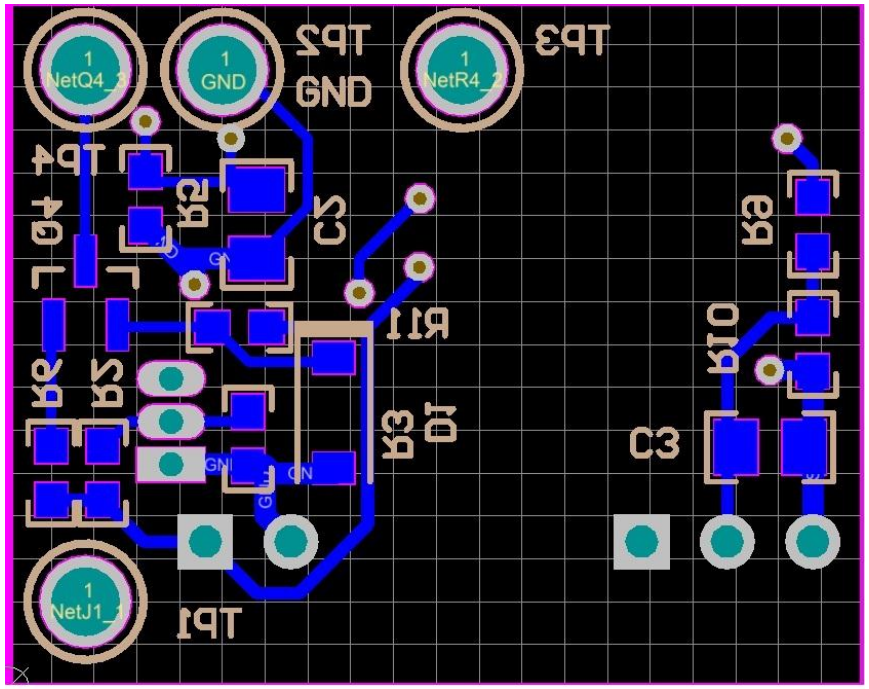

Figure 19: Bottom Layer and Bottom Overlay Daughter Board (Bottom view)

6 Bill of Materials

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

REFERENCE DESIGNATOR	QTY	VALUE	DESCRIPTION	SIZE	MFR	PART NUMBER
C1	1	0.1 μF	CAP FILM 0.1UF 630VDC RADIAL	13 x 6mm	EPCOS	B32921C3104M
C2,C3	2	0.22 μF	CAP FILM 0.22UF 630VDC RADIAL	18 x 7mm	EPCOS	B32922C3224K
C4	1	0.01 μF	CAP, CERM, 0.01uF, 1000V, X7R, 10%	1808	Vishay	VJ1808Y103KXGAT
C5,C13	2	4700 pF	CAP, CERM, 4700pF, 500VAC, Y1, 20%,	10mm	Vishay	VY1472M63Y5UQ63V0
C6,C7	2	1 μF	CAP, CERM, 1uF, 100V, +/-10%, X7R	1206	MuRata	GRM31CR72A105KA01L
C8	1	1000 μF	CAP, Aluminum, 1000uF, 63V, +/-20%	16 x 35mm	Panasonic	UPW1J102MHD6
C9	1	47 μF	CAP, Aluminum, 47uF, 25V, +/-20%	5 x 11mm	Panasonic	EEU-EB1E470S
C10,C11	2	0.1 μF	CAP, CERM, 0.1uF, 25V, +10/%, X7R	0603	MuRata	GRM188R71E104KA01D
C12	1	2.2 μF	CAP, CERM, 2.2uF, 16V, +10/%, X7R	0805	TDK	C2012X7R1C225K
C14	1	1 μF	CAP, CERM, 1uF, 25V, +10/%, X5R	0805	MuRata	GRM216R61E105KA12D
C15	1	0.33 μF	CAP, CERM, 0.33uF, 16V, +10/%, X7R	0603	Kemet	C0603C334K4RACTU
C16,C17,C18	3	0.01 μF	CAP, CERM, 0.01uF, 100V, +10/%, X7R	0603	AVX	06031C103KAT2A
C19	1	10 μF	CAP, CERM, 10uF, 35V, +/-20%, X7R	1210	Taiyo Yuden	GMK325AB7106MM-T
C20	1	330 pF	CAP, CERM, 330pF, 630V, +/-5%, C0G/NP0	1206	TDK	C3216C0G2J331J
D1	1	16V	Diode, Zener, 16V, 500mW	SOD-123	On Semi	MMSZ4703T1G
D2	1	12V	Diode, Zener, 12V, 500mW	SOD-123	On Semi	MMSZ4699T1G
D3	1	800V	Diode, Bridge, 800V, 0.5A	4-SOIC	Fairchild	MB8S
D4	1	800V	Diode, Ultrafast, 800V, 1A	SMA	Vishay	US1K-E3/61T
D5	1	600V	DIODE ULT FAST 600V 3A	SMB	ST	STTH1R04U
D6	1	100V	Diode, Small Signal, 100V, 200 mA	SOT-23	Fairchild	MMBD1204
D7,D8	2	24V	Diode, Zener, 24V, 500mW	SOD-123	On Semi	MMSZ4709T1G
D9	1	100V	Diode, Fast, 100V, 200mA	SOD-123	Diodes	BAV19W-7-F
F1	1	3A	Fuse, 3A, 350VAC,	10.92mm x 8.76mm x 3.81mm	Littelfuse	0447003.YXP
L1	1	22 mH	Common Mode Choke	17 × 22mm	Taiyo Yuden	TLF14CB2230R4K1
L2	1	2.2 mH	INDUCTOR 2200UH 0.62A	13 x 16mm	Colicraft	RFS1317-225KL
Q1	1	950V	MOSFET, N-CH, 950V, 12A	TO-220FP	ST	STF15N95K5
Q2, Q3	2	40V	Transistor, NPN, 40V, 0.2A,	SOT-23	Fairchild	MMBT3904
Q4	1	40V	PNP Transistor	SOT-23	Diodes	MMBT3906-7-F
R1,R2,R22,R23	4	549k Ω	Resistor, Chip, 1/4W, 1%	1206	std	
R3	1	4.99 Ω	Resistor, Chip, 1/10W, 1%	0603	Std	
R4	1	100k Ω	Resistor, Chip, 1W, 5%	2512	Std	
R5	1	3.01 Ω	Resistor, Chip, 1/10W, 1%	0603	std	
R6	1	115 kΩ	Resistor, Chip, 1/10W, 1%	0603	Std	
R7	1	100 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R8	1	23.2 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	

R9, R21	2	49.9 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R10	1	49.9 Ω	Resistor, Chip, 1/4W, 1%	1206	std	
R11,R13,R17,R18,R26	5	10.0 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R12	1	0.33 Ω	Resistor, Chip, 1/2W, 1%	1210	Std	
R14	1	100k Ω	Resistor, Chip, 1/4W, 5%	1206	std	
R15	1	2.00 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R16	1	20.0 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R19	1	34.0 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R20	1	1.5 MΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R24	1	66.5 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
T1	1		Transformer	ER28	Wurth	750811693
U1	1		High Efficiency, Offline LED Lighting Driver Controller with Current Mode Control		Texas Instruments	TPS92210D
U2	1		OptoCoupler	4-SMD	Fairchild	FOD817DS
U3	1	5.0V	Precision Micropower Shunt Voltage Reference	SOT-23	Texas Instruments	LM4040AIM3X-5.0
U4	1		Low Power Single Op Amp	SOT-23 5 pin	Texas Instruments	LM321MF
VR1	0					

Table 2: The components list of the Daughter Board according to the schematic shown in Figure 2

REFERENCE DESIGNATOR	QTY	VALUE	DESCRIPTION	SIZE	MFR	PART NUMBER
C1,C2	2	0.01 μF	CAP, CERM, 0.01uF, 100V, +10/%, X7R	0603	AVX	06031C103KAT2A
C3	1	22 μF	CAP, CERM, 22uF, 6.3V, +20/%, X5R	0805	Murata	GRM21BR60J226ME39L
D1	1	15V	Diode, Zener, 15V, 500mW	SOD-123	On Semi	MMSZ4702T1G
Q1	1	40V	Transistor, Progrmmable Unijunction 40V, 300mW TO-92	TO-92	On Semi	2N6027
Q2	1	40V	PNP Transistor	SOT-23	Diodes	MMBT3906-7-F
R1	1	1.0 MΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R2	1	30.1 kΩ	Resistor, Chip, 1/10W, 1%	0603	Std	
R3	1	13.3 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R4,R7,R8	1	10.0 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R9	1	143 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R10	1	4.75 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
R11	1	200 kΩ	Resistor, Chip, 1/10W, 1%	0603	std	
U1	1		OptoCoupler	4-SMD	Fairchild	FOD817DS
U2	1		Low Power Low Offset Voltage Dual Comparator	8-SOIC	Texas Instruments	LM393M

EVALUATION BOARD/KIT/MODULE (REF DESIGN) WARNINGS, RESTRICTIONS AND DISCLAIMER

For Feasibility Evaluation Only, in Laboratory/Development Environments. The REF DESIGN is not a complete product. It is intended solely for use for preliminary feasibility evaluation in laboratory / development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical / mechanical components, systems and subsystems. It should not be used as all or part of a production unit.

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2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the REF DESIGN. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the REF DESIGN and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. Since the REF DESIGN is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the REF DESIGN will not result in any property damage, injury or death, even if the REF DESIGN should fail to perform as described or expected.

Certain Instructions. Exceeding the specified REF DESIGN ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the REF DESIGN and/or interface electronics. Please consult the REF DESIGN User's Guide prior to connecting any load to the REF DESIGN output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output ranges are maintained at nominal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be indentified using the REF DESIGN schematic located in the REF DESIGN User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch.

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