Using the TPS92210-PMP6001

Reference Guide

Literature Number: SLUU478
January 2011

Reference Guide

SLUU478–January 2011

A Universal Input 38-V, 350-mA, Non-Dimmable LED Driver

1 Introduction

This reference design is a single-stage, power factor corrected LED lighting driver using TPS92210. The driver will work with AC mains from 90 V_{RMS} to 265 V_{RMS} and provide a constant current 350 mA to drive 12 high-brightness (HB) LEDs.

2 Description

Based on a TPS92210 control chip, this LED lighting driver design is capable of providing high power factor, load protection and extended life in a small volume at low cost. It employs constant “on-time” and critical, or discontinuous, conduction mode in an isolated flyback configuration. Intended for low power lighting applications, it can be packaged in a variety of ways including individual lamp designs and generic PCB form for many types of luminaries.

2.1 Typical Applications

- Light Bulb Replacement (LBR)

2.2 Features

- 90-V_{RMS} to 265-V_{RMS} Offline Operation
- Power Factor Correction
- Constant Current Control
- Output Isolation

3 Electrical Performance Specifications

Table 1. PMP6001 Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range		90		265	V_{RMS}
PF		0.99			
THD				12	%
Output Characteristics					
Output voltage, V_{OUT}	Output current = 350mA		38		V
Output load current, I_{OUT}			350		mA
Systems Characteristics					
Efficiency			81		%

4 Schematic

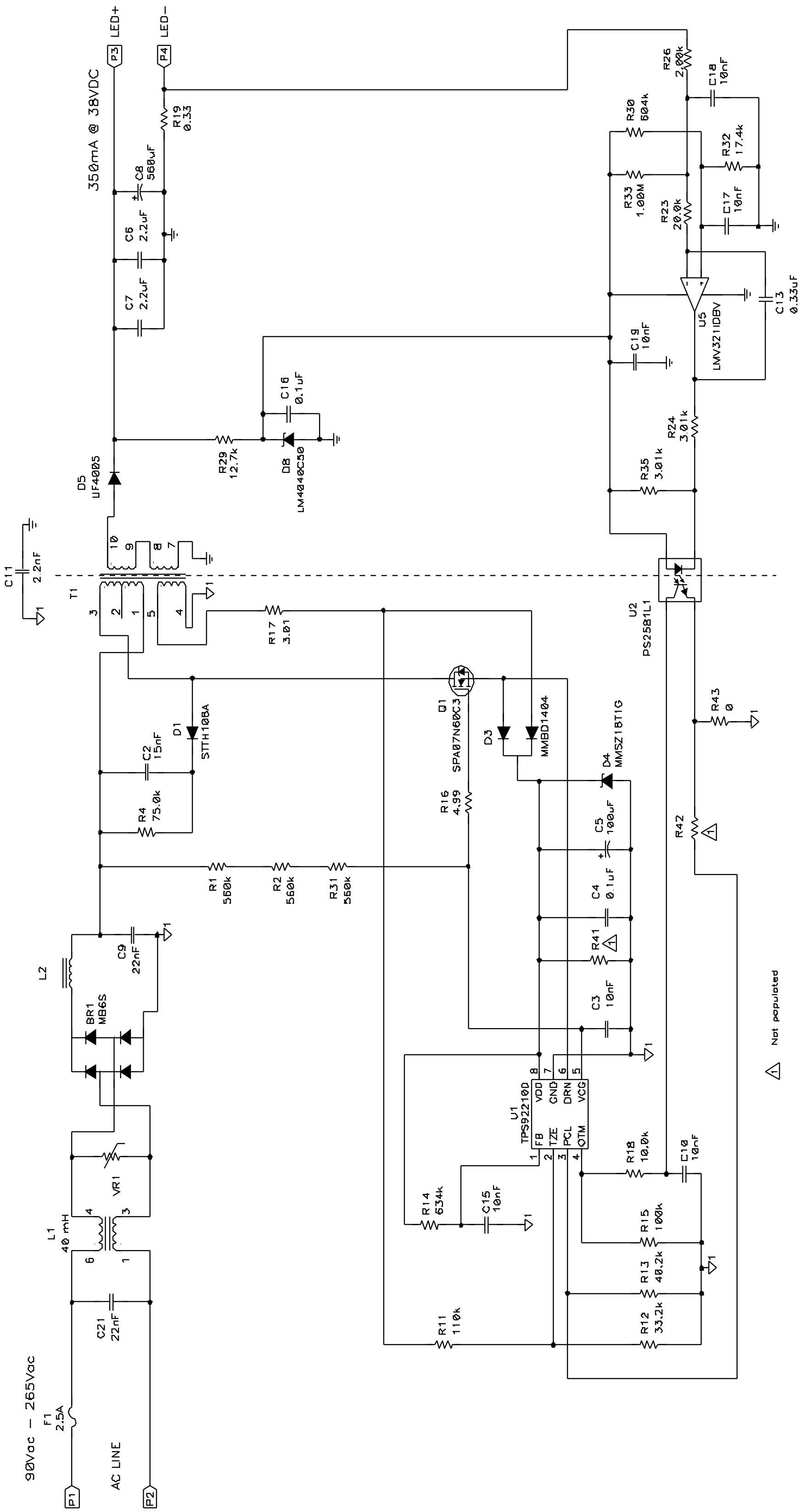

Figure 1. PMP6001 Schematic

5 Theory of Operation

5.1 Single Stage Power

Any single-stage, AC/DC converter topology that can be coerced into drawing a sinusoidal current from the AC line can be considered a single stage power factor corrected converter.

Referring to Figure 2, the TPS92210 controller can be programmed to operate at a fixed frequency with a constant on-time for the internal switch which drives the primary power FET. Configured in a cascode arrangement, the TPS92210 output driver provides current control without an external sense resistor.

Because the on-time of the cascode switch is constant, peak inductor current that is reached during each switching cycle will depend on the primary inductance and the instantaneous supply voltage. Primary inductance is fixed, and the power switch on-time is constant, so the peak current each cycle will be directly proportional to source voltage.

$$I_{PRIM(peak)} = \frac{V_{BULK} \times t_{ON}}{L_{PRIM}} = \frac{V_{BULK}}{k} \quad \text{where} \quad k = \frac{L_{PRIM}}{t_{ON}} \tag{1}$$

The variable k has the units Henrys/seconds which is equivalent to Ohms. Under these conditions the power stage will have the same transfer function as a resistor, and a power factor of 1. Variations in primary inductance or on-time of the cascode switch may lead to degradation in power factor.

Figure 2 shows the TPS92210 operating as a fixed on-time, fixed frequency, flyback controller with no feedback, resulting in a power stage with very high power factor, very low THD, and unconditional stability resulting from the elimination of control loop dynamics. In the absence of feedback the load voltage and current are not regulated but instead the total power delivered to the secondary load is directly proportional to the rms line voltage and is a function of the programmed on-time, PWM frequency, primary inductance, and power stage conversion efficiency. The TPS92210 frequency error is trimmed to less than 5%, the on-time modulation accuracy is specified as less than 10%, and so with a 10% tolerance primary inductance, output power control with such a minimum system can be held to within about 25% with additional variations due to line voltage. Although the controller is running open loop in this example, programmable isolated output over-voltage protection is still be available, and power limiting and overload protection is still active.

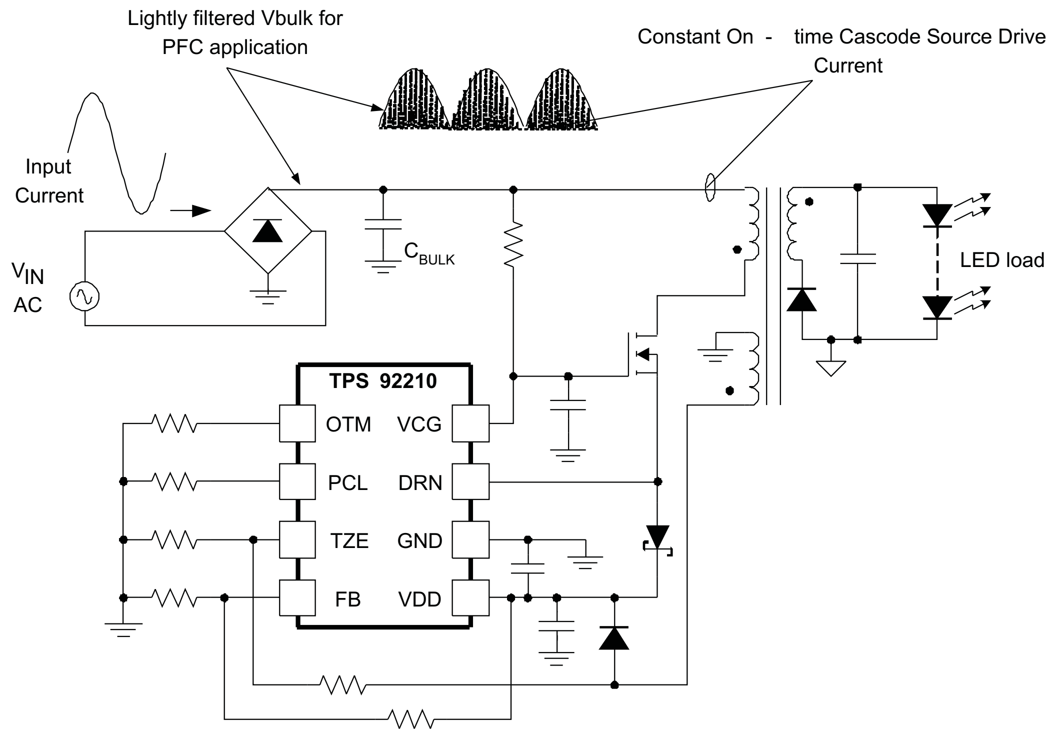

Figure 2. Input Current Tracks Input Voltage in Constant On-Time Flyback

---

NOTE: V_{BULK} in Equation 1 represents the source voltage during each switching cycle. C_{BULK}, in Figure 2, is reduced to a switching frequency bypass role providing no DC support. Consequently, the source voltage has the form of a rectified sine wave and input current will track input voltage with very good fidelity, yielding a high power factor. Notice also in the diagram of Figure 2, there are no "hard" edges in the input current waveform and consequently few significant harmonics.

If high load ripple current, at twice the line frequency, is tolerable, then the circuit in this example can easily be constructed with no electrolytic capacitors. Absent electrolytic capacitors and opto-coupler the circuit in this example has the potential for very high reliability if components are carefully chosen and properly de-rated for voltage, current, and operating temperature.

5.2 TPS92210 Controller

Operation and features of the TPS92210 are detailed in the TPS92210 data sheet (TI LIterature Number SLUS989) for that controller. Briefly, the device features of interest here are associated with programming it to provide fixed frequency, adjustable maximum current (sensing the power inductor current) and flyback period sensing to assure discontinuous operation.

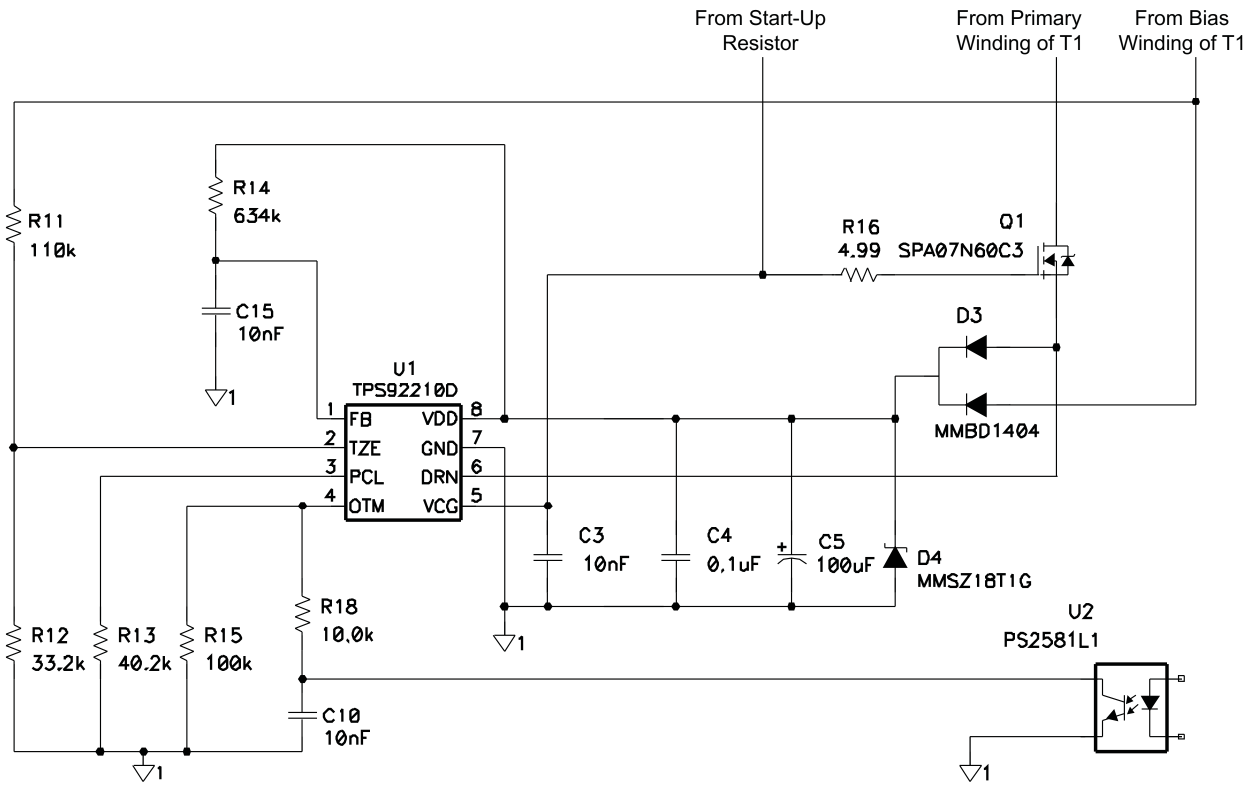

Figure 3. TPS92210 Control Chip
(Driving Q1 with programmable on-time)

Drive to the main power switch, Q1, uses a cascode arrangement in which and internal drive transistor switches source current in Q1 allowing inductor current to be measured within the TPS92210 without need for an external current sense resistor.

NOTE: Note that Q1 gate and source connections are made directly to the controller. Power for the controller (V_{DD}) comes from an auxiliary winding on the power inductor through D3 filtered and limited by D4, C4 and C5.

V_{DD} is also used to program fixed frequency operation by injecting current into the FB (Feedback) pin on the TPS92210, through R14. In this design, the programming current is approximately:

$$\frac{18\,V}{634\,k\Omega} = 28\,\mu A \tag{2}$$

Yielding an operating frequency of 110 kHz.

A non-rectified signal from the inductor auxiliary winding is routed via a divider, R11 and R12 to the TZE pin where it is used to detect demagnetization of the transformer by observing the zero crossing of the signal. By re-enabling another forward drive pulse to Q1 after the flyback period has ended the controller insures that discontinuous switching mode prevails so that all the energy stored in the power inductor is transferred to the load on each cycle. Enabling at a voltage minimum allows for smaller switching loss per cycle.

In the configuration of this reference design, PCL the current modulation input to the TPS92210 is not used, so it is terminated to ground via R13 which programs the peak current value at which the controller cuts off drive to Q1. This is ordinarily the point where current sensing is done in converters using current mode control. Instead, maximum on-time is programmed at pin 4 (OTM) by R15. OTM supplies a current that is used to program an internal voltage (R15) that sets maximum on-time. Notice that the primary-side opto-coupler transistor can divert some of the current from the OTM pin through R18 thereby reducing the maximum on-time according to output current sensed on the secondary side. Maximum on-time modulation provides the feedback scheme for LED current control.

5.3 Secondary-Side Current Feedback

The main output channel on the driver secondary side is a conventional flyback configuration consisting of D5 and several filter capacitors, C6, C7, and C8. Current sense resistor R19 converts LED load current to a ground referenced voltage.

LED current amplitude information taken from R19 is compared by integrator U5 to a reference formed by R30 and R32, amplifies the difference and drives the LED half of the opto-coupler U2 used to control maximum main switch on-time. This configuration yields closed loop current regulation for the load LEDs. Increasing load current forces U5 to increase opto-coupler drive which reduces the resistance at OTM on the TPS92210. Lower net resistance at the OTM pin causes the on-time to narrow thus reducing power to the secondary to counteract the increase in load current.

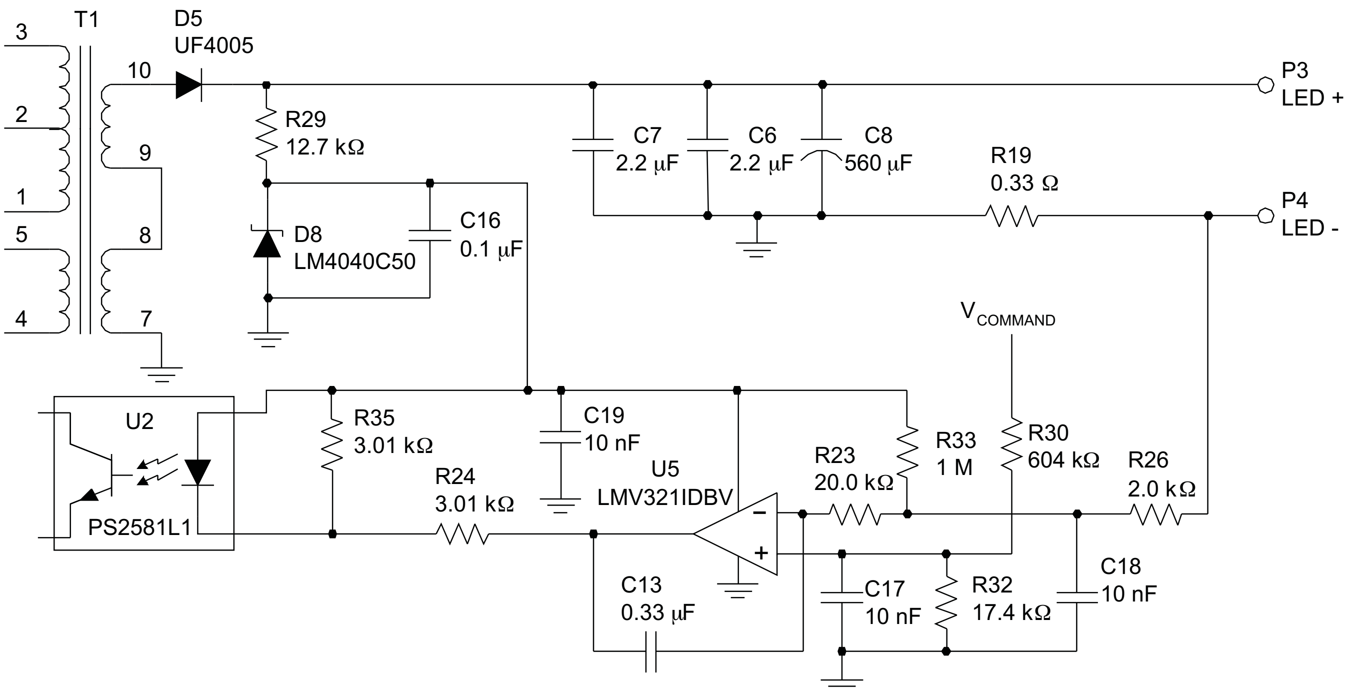

Figure 4. Secondary-Side Load Current Channel

6 Layout

This reference design has been implemented on a double-sided PCB that is dimensionally compatible with Luminaires that fit PAR38 and similar applications. It has been made physically small to show the practicality of a single-stage PF correcting converter using a TPS92210 control device. Moreover, the PCB has been universally designed for various applications. Only the components in components list (Table 2) are needed for this reference design.

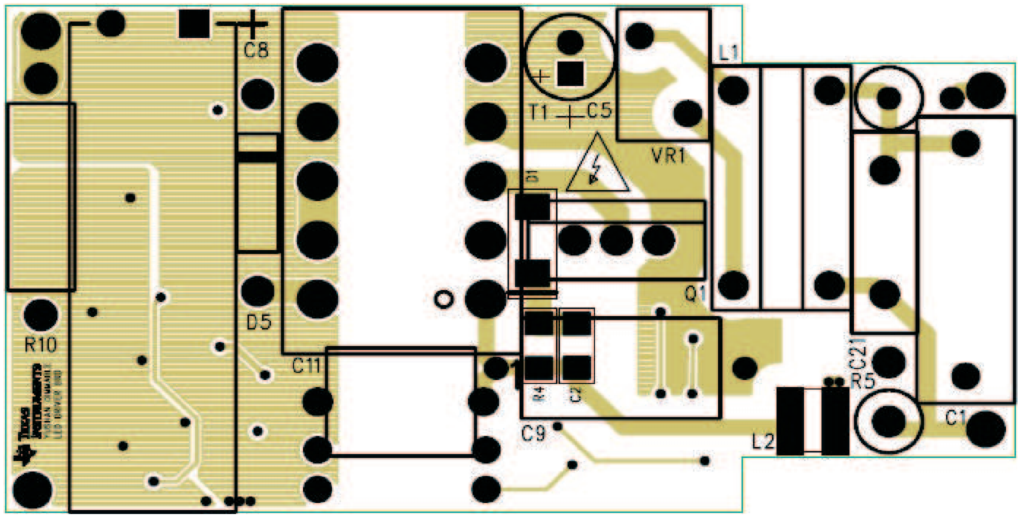

Figure 5. Top Side of PMP6001 PCB Layout

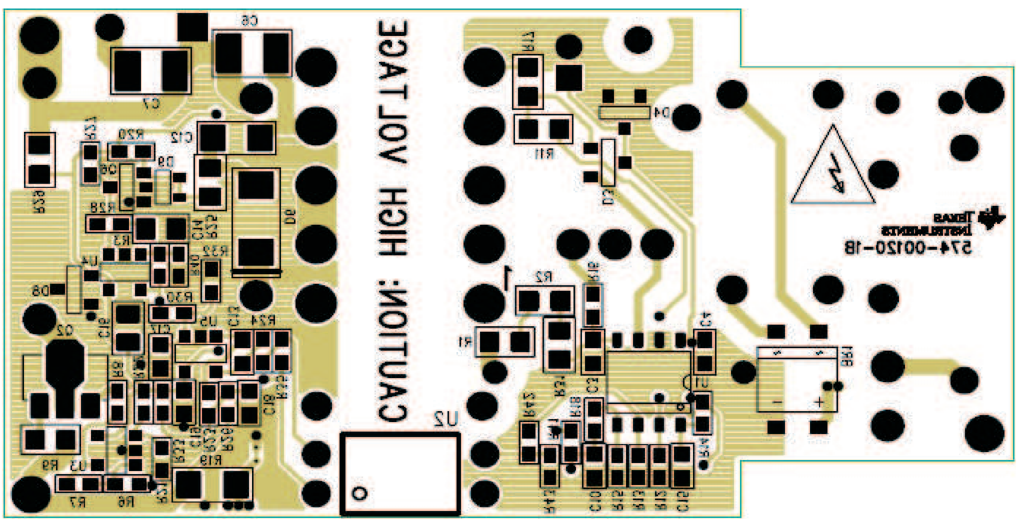

Figure 6. Bottom Side of PMP6001 PCB Layout

7 Performance Data and Typical Characteristic Curves

Figure 7 to Figure 12 present typical performance curves for PMP6001 38-V, 350-mA, dimmable LED Driver.

7.1 Power Factor (PF)

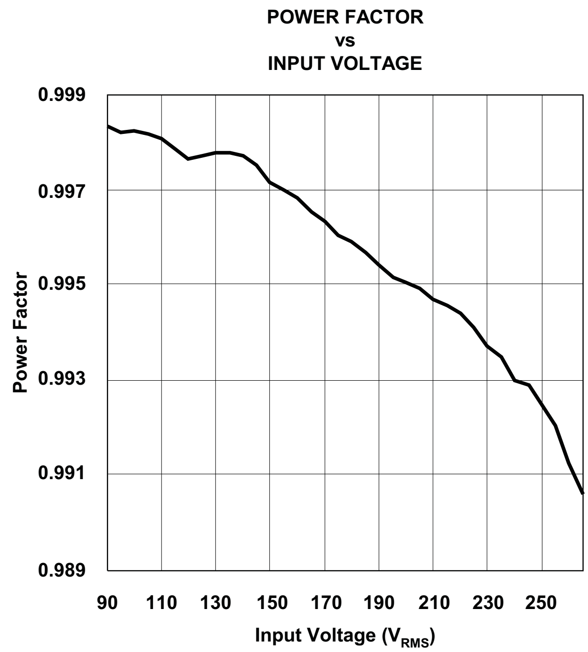

Figure 7.

7.2 Total Harmonic Distortion (THD)

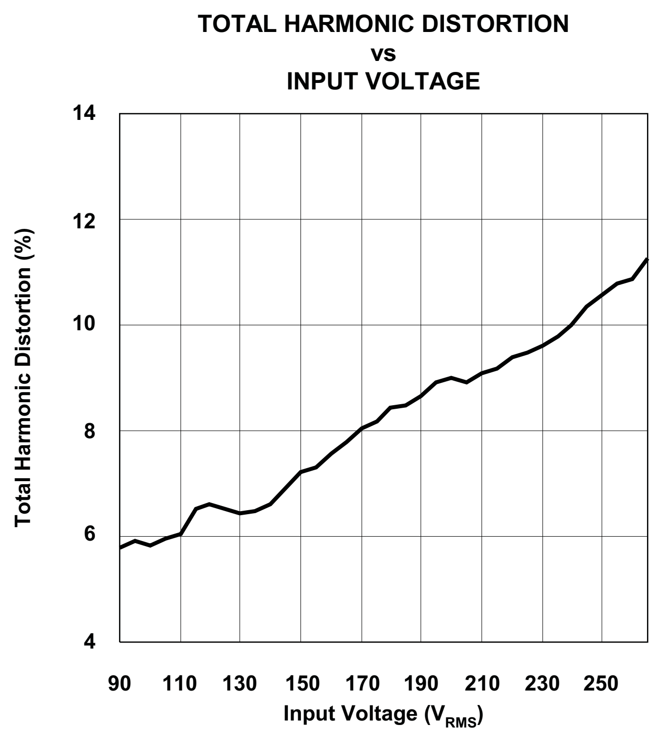

Figure 8.

7.3 Output Current (I_{OUT})

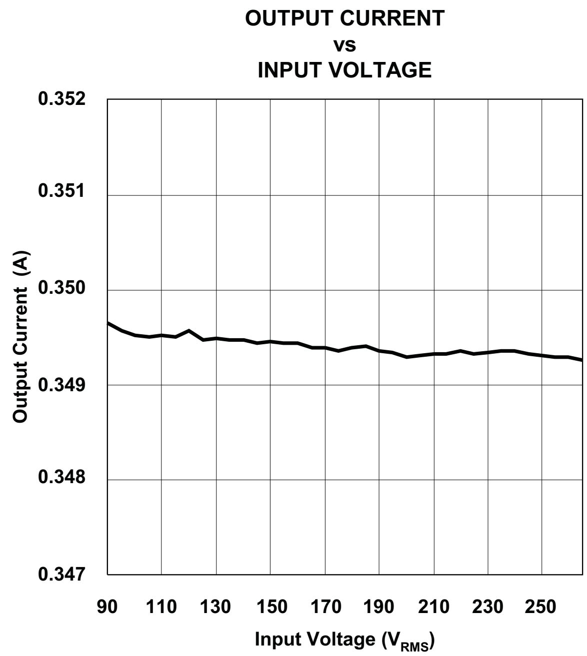

Figure 9.

7.4 Output Voltage (V_{OUT})

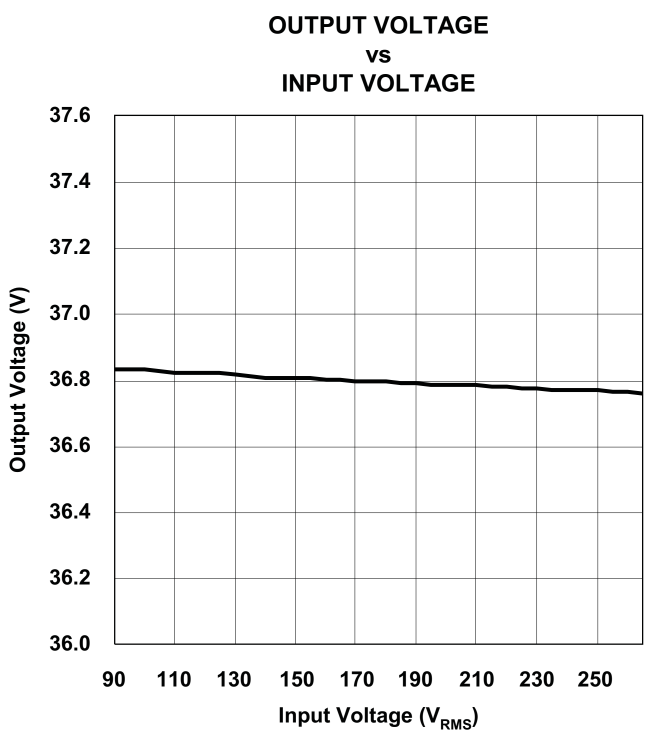

Figure 10.

7.5 Output Power (P_{OUT})

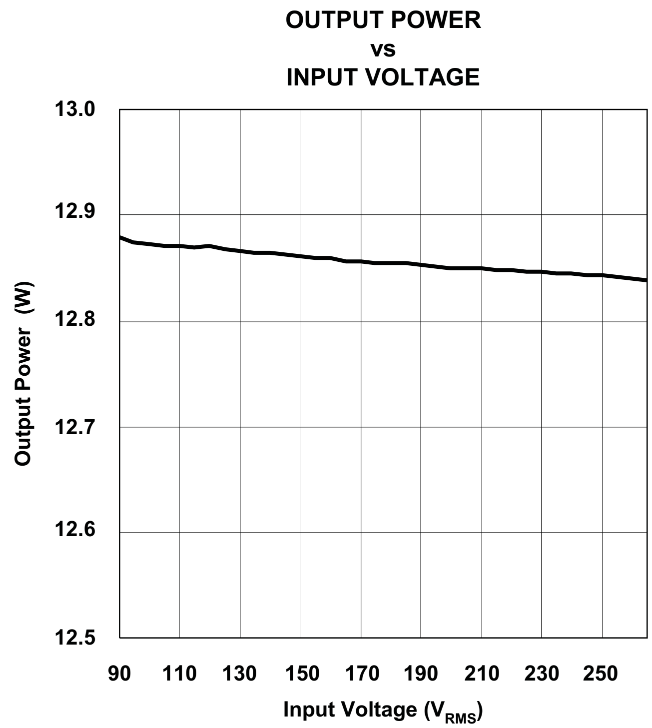

Figure 11.

7.6 Efficiency

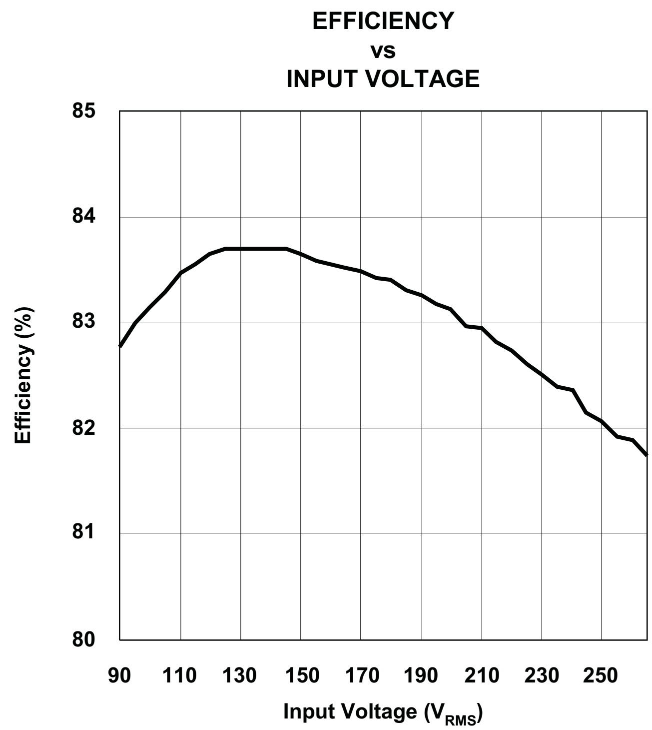

Figure 12.

8 List of Materials

Table 2. PMP6001 Components List

QTY	REF DES	DESCRIPTION	MFR	PART NUMBER
1	C2	Capacitor, ceramic, 15000 pF, 250 V, X7R, 1206	Std	Std
1	C3	Capacitor, ceramic, 10000 pF, 50 V, X7R, 0603	Std	Std
1	C4	Capacitor, ceramic, 0.1 µF, 50 V, X7R, 10%, 0603	Std	Std
1	C5	Capacitor, elect radial, 100 µF, 25 V, 2.5 mm	Std	Std
2	C6,C7	Capacitor, ceramic, 2.2 µF, 100 V, X7R, 1210	Std	Std
1	C8	Capacitor, elect he radial, 560 µF, 50 V	Std	Std
1	C9	Capacitor, metal poly, 0.022 µF, 630 VDC	Panasonic	ECQ-E6223KF
5	C10,C15, C17,C18, C19	Capacitor, ceramic, 10000 pF, 25 V, X7R, 0603	Std	Std
1	C11	Capacitor, ceramic radial, 2.2 nF, X1/Y1,	muRata	DE1E3KX222M
1	C13	Capacitor, ceramic, 0.33 µF, 16 V, X7R, 0603	Std	Std
1	C16	Capacitor, ceramic, 0.1 µF, 25 V, 0805	Std	Std
1	C21	Capacitor, metal polypro, 0.022 µF, 305 VAC, X2	Epcos	B32921C3223M
1	D1	Diode, ultra fast, 800 V, 1 A, SMA	ST	STTH108A
1	D3	Diode, ultra fast, 200 V, SOT-23	Fairchild	MMBD1404
1	D4	Diode, Zener, 18 V, 225 mW, SOT-23	Std	Std
1	D5	Diode, GPP fast, 1 A, 600 V, DO-41	Std	UF4005
1	D8	Shunt, regulator, 5.0 V, SOT-23	TI	LM4040C50
1	F1	Fuse, pico fast, 2.5 A, 250 V, axial	Littelfuse	026302.5WRT1L
1	L1	Inductor, common mode choke, 40 mH	Wurth	750311897
1	L2	Jumper, (res, 0.0 Ω, 1206)	Std	Std
1	Q1	MOSFET, N-channel, 650 V, 7.3 A, TO-220FP	Infineon	SPA07N60C3
1	BR1	Rectifier, bridge, 0.5 A, 600 V, 4SOIC	Diodes	MB6S
3	R1,R2,R3 1	Resistor, 560 kΩ, 1/4 W, 1%, 0805, SMD	Std	Std
1	R4	Resistor, 75.0 kΩ, 1/4 W, 1%, 1206, SMD	Std	Std
1	R11	Resistor, 110 kΩ, 1/8 W, 1%, 0805, SMD	Std	Std
1	R12	Resistor, 33.2 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R13	Resistor, 40.2 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R14	Resistor, 634 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R15	Resistor, 100 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R16	Resistor, 4.99 Ω, 1/10 W, 1%, 0603, SMD	Std	Std
1	R17	Resistor, 3.01 Ω, 1/8 W, 1%, 0805, SMD	Std	Std
1	R18	Resistor, 10.0 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R19	Resistor, .33 Ω, 1/4 W, 1%, 1206, SMD	Std	Std
1	R23	Resistor, 20.0 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std

Table 2. PMP6001 Components List (continued)

QTY	REF DES	DESCRIPTION	MFR	PART NUMBER
2	R24,R35	Resistor, 3.01 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R26	Resistor, 2.00 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R29	Resistor, 12.7 kΩ, 1/8 W, 1%, 0805, SMD	Std	Std
1	R30	Resistor, 604 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R32	Resistor, 17.4 kΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R33	Resistor, 1.00 MΩ, 1/10 W, 1%, 0603, SMD	Std	Std
1	R41	DNL		
1	R42	DNL		
1	R43	Resistor, 0.0 Ω, 1/20 W, 5%, 0603, SMD	Std	Std
1	T1	Transformer, flyback, EE20/10/6	Wurth	750811146
1	U1	PWM, controller cascode, 8-SOIC	TI	TPS92210
1	U2	Opto isolator transistor output	CEL/NEC	PS2581L1
	U4	Add jumper between pin 4 & 5		
1	U5	Opamp, GP, R-R, 1 MHZ, SGL, SOT23-5	TI	LMV321IDBVR
1	VR1	Zinc-oxide varistor, 220 VDC, 1.25KA	Panasonic	ERZ-V07D431