TPS92513EVM-001 High-Current Buck Regulator With Analog and PWM Dimming for High Brightness LEDs

This user's guide describes the characteristics and use of the high-current buck light-emitting diode (LED) driver evaluation module.

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1 Introduction

The TPS92513EVM-001 evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92513HV buck switching regulator designed for high-current LED drive applications. The TPS92513 is designed to control the drive of high-brightness LEDs and features a wide input voltage range (4.5 V to 60 V), PWM dimming capability, analog dimming capability, adjustable/syncable switching frequency, and input undervoltage protection.

2 Warnings and Cautions

Observe the following precautions when using the TPS92513EVM-001.

WARNING



When choosing your LED component (not included with this EVM) the end user must consult the LED data sheet supplied by the LED manufacturer to identify the EN62471 Risk Group Rating and review any potential eye hazards associated with the LED chosen. Always consider and implement the use of effective light filtering and darkening protective eyewear and be fully aware of surrounding laboratory-type set-ups when viewing intense light sources that may be required to minimize or eliminate such risks in order to avoid accidents related to temporary blindness.

3 Description

The TPS92513EVM-001 provides a high-brightness LED driver based on the TPS92513 buck regulator. It is designed to operate with an input voltage in the range of 6 V to 24 V. The EVM is set up for a default output current of 1 A for an LED stack between approximately 2.5 V and 16 V (depending on the input voltage). The TPS92513 helps provide high efficiency, good line regulation, low output ripple, and a wide dimming range.

3.1 Typical Applications

This converter design describes an application of the TPS92513 as an LED driver with the specifications listed below. For applications with a different input voltage range or different output voltage range, refer to the TPS92513 datasheet (SLVSCX6).

3.2 Features

3.2.1 Connector Description

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92513EVM-001.

3.2.1.1 LED+, LED–

The test posts marked LED+ and LED– are for connecting the LED load to the board. The leads to the LED load should be twisted and kept as short as possible to minimize voltage drop, inductance, and EMI transmission. This design is for approximately 1 to 5 white LEDs.

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3.2.1.2 VIN, GND

The test posts marked VIN and GND are for connecting the EVM to the DC input voltage supply. The input supply ground should be connected to the GND test post and not to the GND test point next to the IADJ test point.

3.2.1.3 UVLO

The test point UVLO connects directly to the UVLO pin of the TPS92513. The voltage range is 0 V to 4.5 V, if driven externally. The UVLO resistor divider should be used for the UVLO function, but the UVLO voltage can be monitored via this test point. Pulling UVLO to GND will also serve to disable the part and put it into low-power shutdown mode.

3.2.1.4 PDIM

The PDIM test point connects directly to the PDIM pin of the TPS92513. Leave open for normal operation. If PWM dimming is used, apply a square wave with a low level of GND and a high level of between 2 V and 4.5 V. The dimming frequency range is 100 Hz to 1 kHz.

3.2.1.5 SYNC

The SYNC test point is AC-coupled to the RT/CLK pin of the TPS92513 through a 4.02-kΩ resistor in series with a 470-pF capacitor. Apply a square wave with a low level of GND and a high level of 3.3 V to synchronize the switching frequency to the applied frequency. The frequency range of SYNC is 200 kHz to 2 MHz.

3.2.1.6 IADJ

The IADJ test point connects to the IADJ pin of the TPS92513 through a 1-kΩ resistor. The default is pulled high through a 10-MΩ resistor to VIN, resulting in an ISENSE voltage of 300 mV. The range on the IADJ test point and pin is 0 mV to 1.8 V and the corresponding ISENSE voltage is V_{IADJ} / 6.

3.2.1.7 PH

A large via labeled *PH* is included and sized specifically to receive the probe tip of a standard 10x probe. Use this via to monitor the switching waveform at the PH pin of the device.

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4 Electrical Performance Specifications

Table 1 lists the electrical performance specifications.

Table 1. TPS92513EVM-001 Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	Units
Input Characteristics					
Voltage range		6		24	V
Maximum input current			1		A
Input UVLO setting		5.7	6	6.3	
Output Characteristics					
Output voltage, VOUT	LED+ to LED–	2.5		16	V
Output current		0.95	1	1.05	A
Output current ripple			20		mApp
Analog dimming range	I_{ADJ} = 180 mV to 1.8 V	10:1			
PWM dimming range	250-Hz PWM	100:1			
Systems Characteristics					
Efficiency	Input voltage = 16 V, 4 LEDs		94		%
Switching frequency			570		kHz

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5 Schematic

Figure 1 displays the EVM schematic.

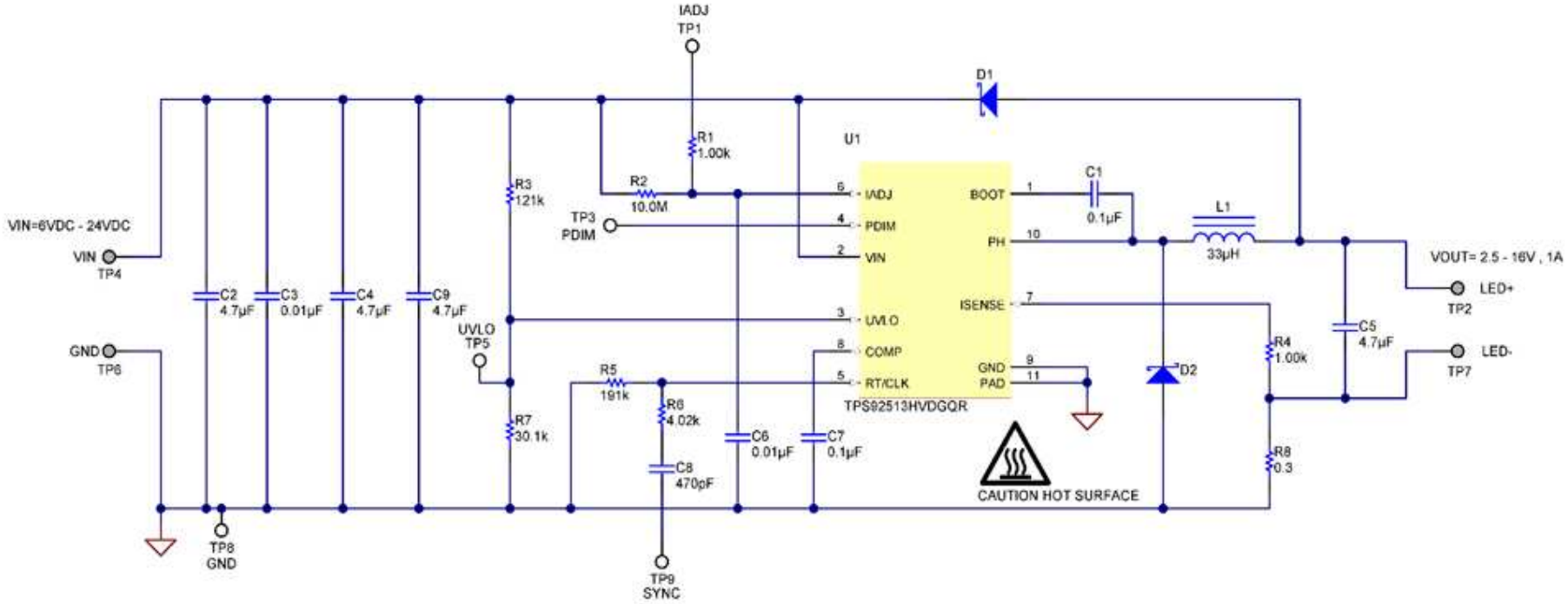


Figure 1. TPS92513EVM-001 Schematic

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6 Performance Data and Typical Characteristic Curves

Figure 2 through Figure 5 present typical performance curves for TPS92513EVM-001. Unless otherwise noted, V_{IN} = 12 V, 2-LED output.

6.1 Efficiency

Figure 2 shows the efficiency versus input voltage graph.

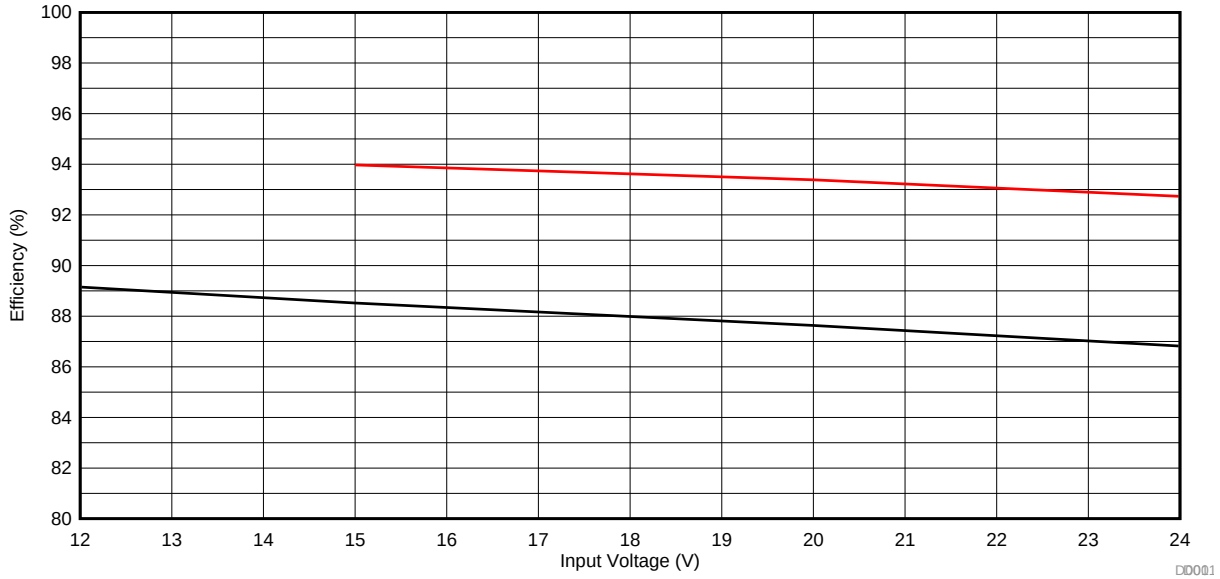


Figure 2. Efficiency vs. Input Voltage, Top = 4 LEDs, Bottom = 2 LEDs

6.2 Line Regulation

Figure 3 shows the output current vs. input voltage.

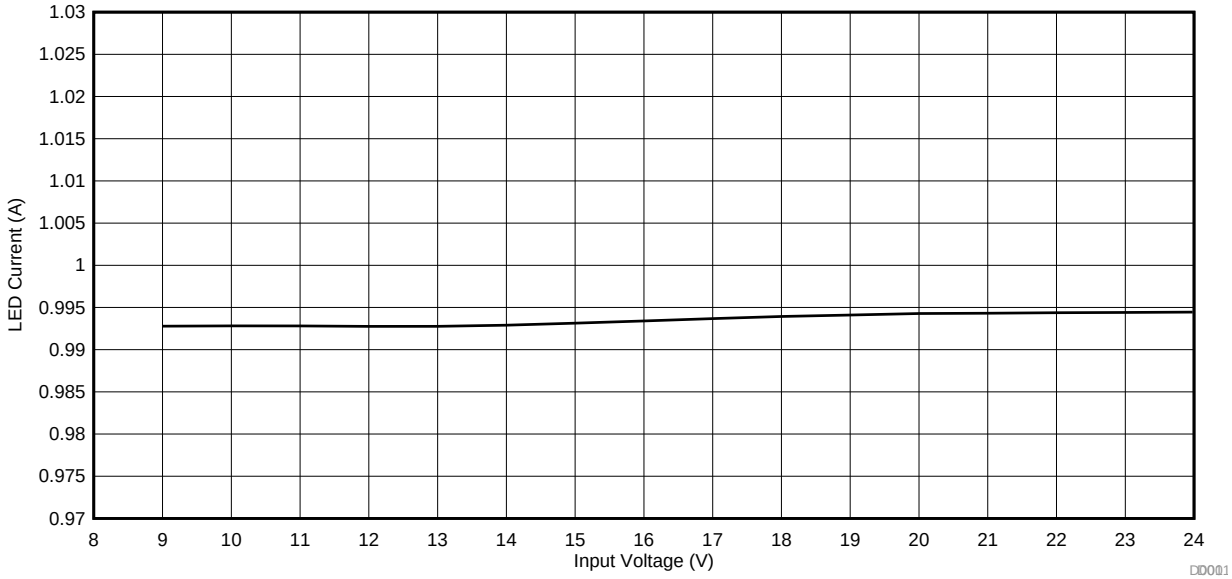


Figure 3. Output Current vs. Input Voltage

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6.3 PWM Dimming

Figure 4 shows the output current versus PWM duty cycle at 250 Hz.

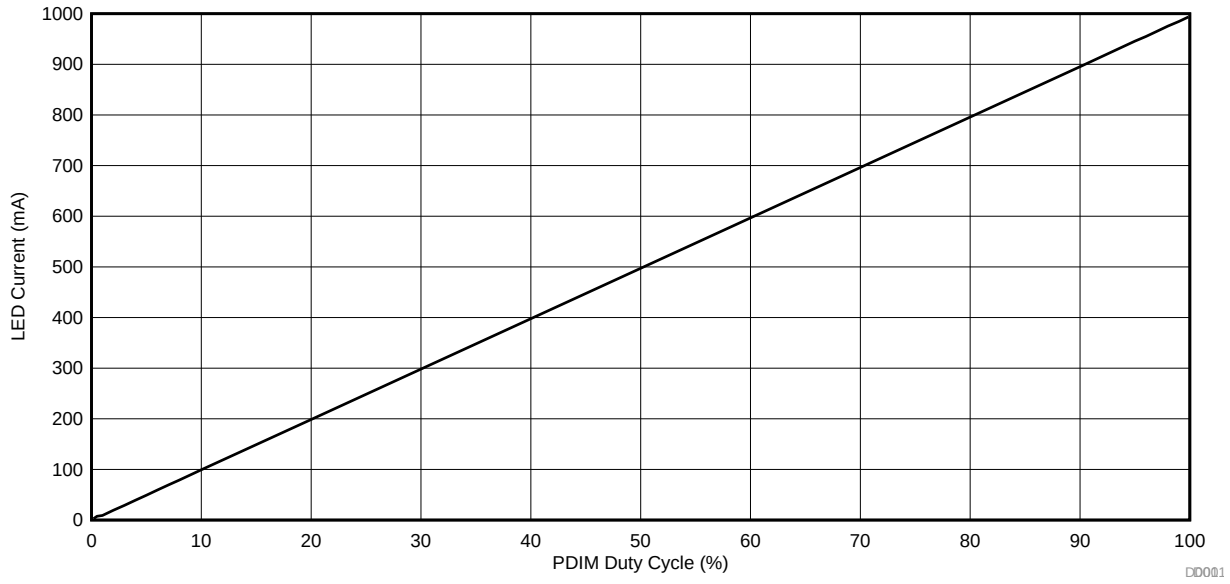


Figure 4. Output Current vs. PWM Duty Cycle (250 Hz)

6.4 Analog Dimming

Figure 5 shows the output current versus I_{ADJ} test point voltage.

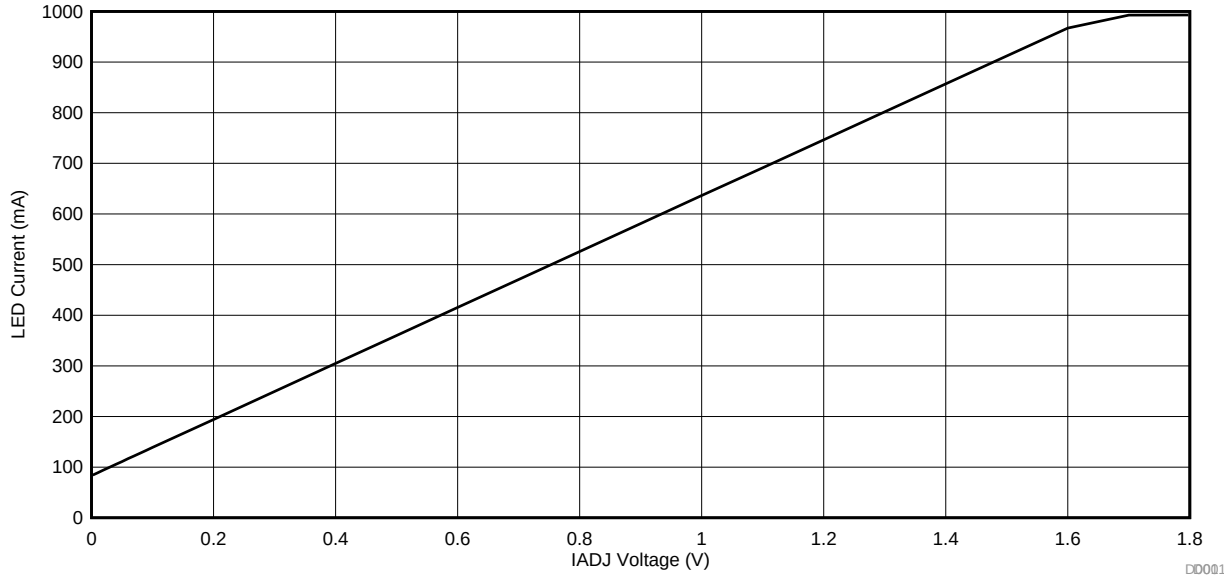


Figure 5. Output Current vs. I_{ADJ} Voltage

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6.5 PWM Dimming Waveforms

Figure 6, Figure 7, and Figure 8 illustrate the PWM dimming waveforms at 1%, 50%, and 99% duty cycles, respectively.

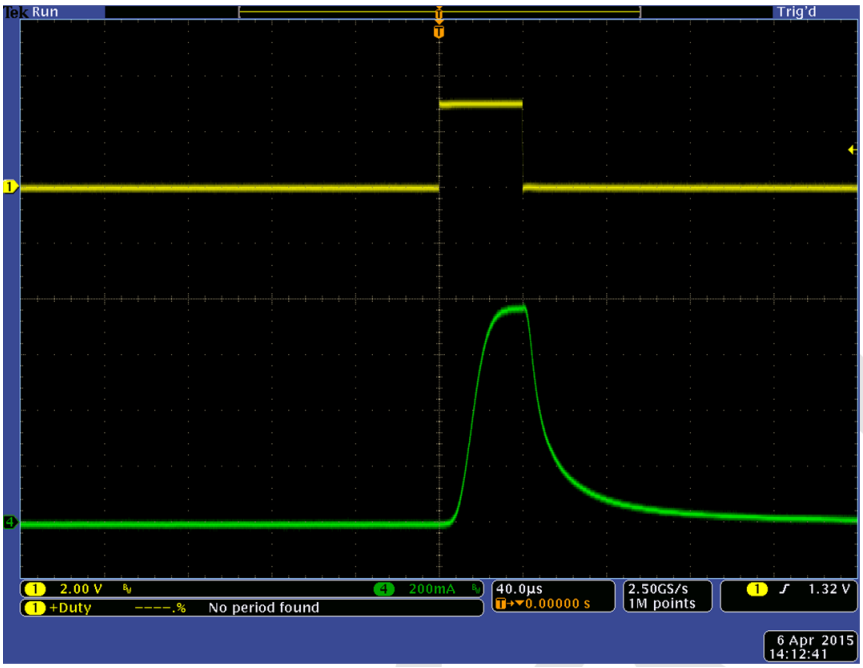


Figure 6. 1% Duty Cycle 250 Hz PWM Dimming, Top = PDIM, Bottom = LED Current

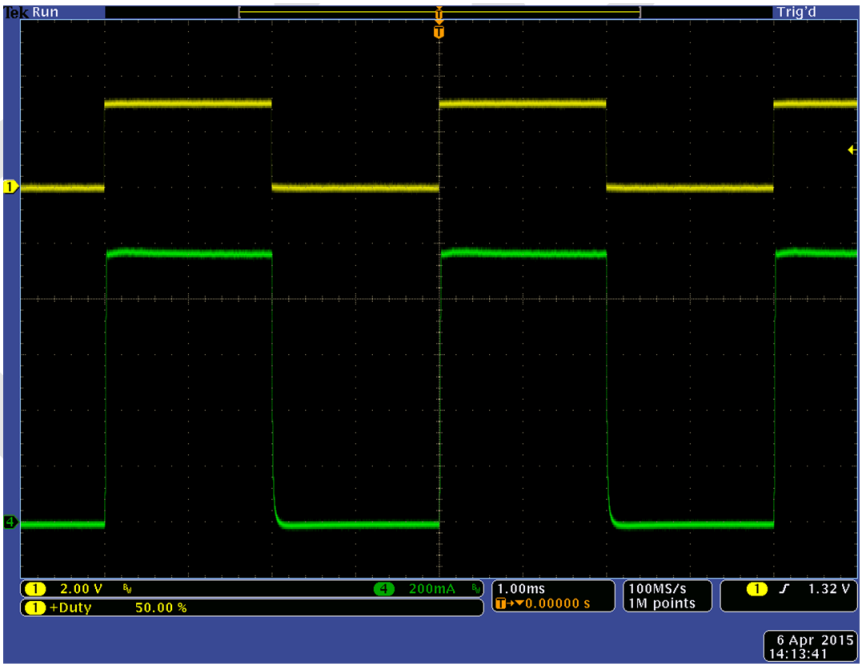


Figure 7. 50% Duty Cycle 250 Hz PWM Dimming, Top = PDIM, Bottom = LED Current

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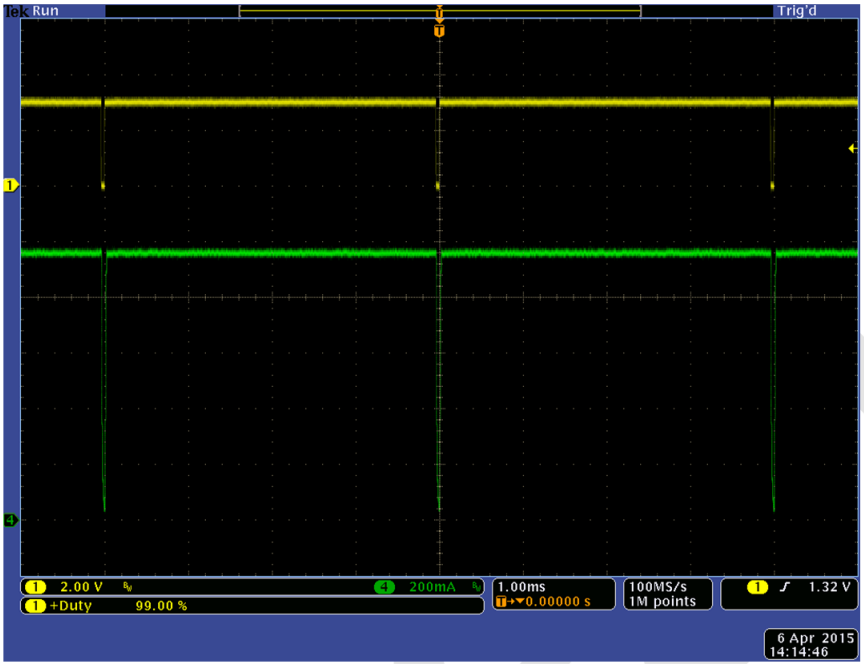


Figure 8. 99% Duty Cycle 250 Hz PWM Dimming, Top = PDIM, Bottom = LED Current

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7 TPS92513EVM-001 PCB Layout

Figure 9 and Figure 10 show the design of the TPS92513EVM-001 printed-circuit board.

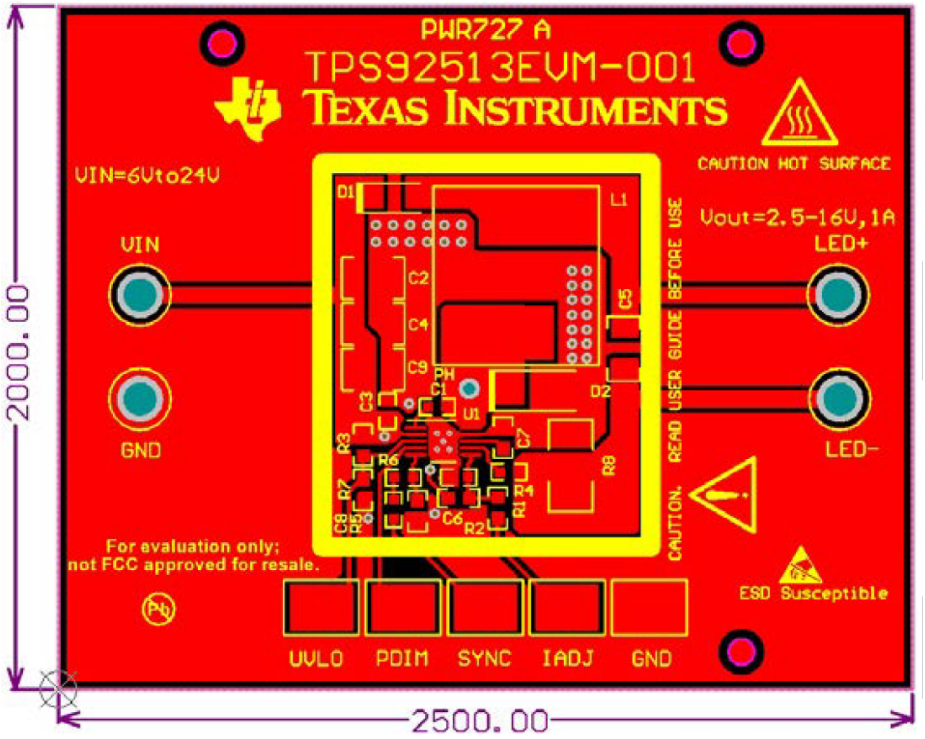


Figure 9. Top Layer and Top Overlay (Top View)

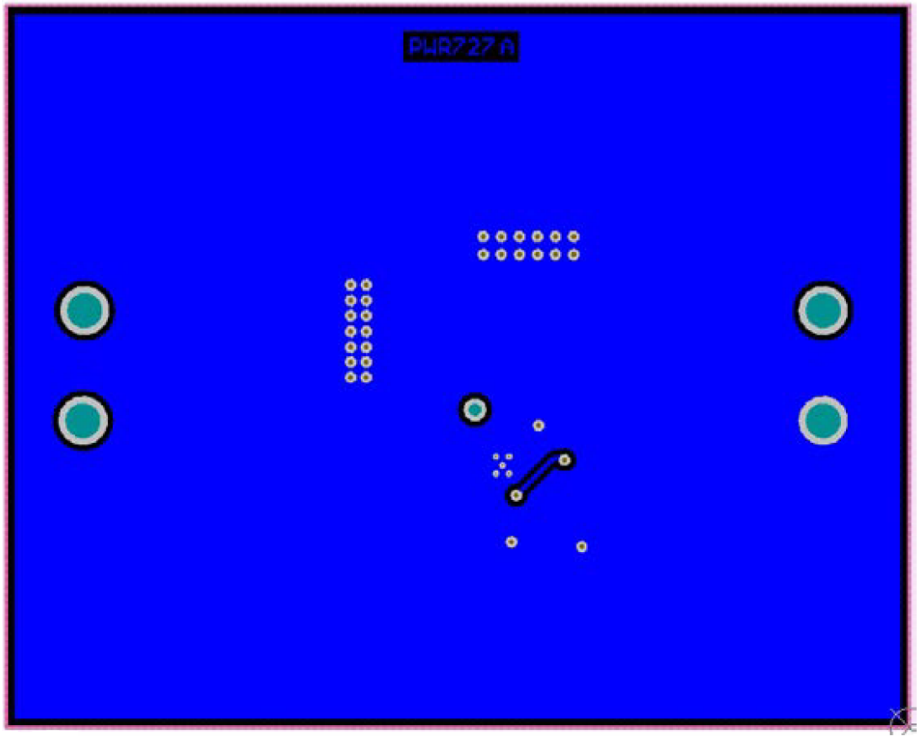


Figure 10. Bottom Layer and Bottom Overlay (Bottom View)

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8 Bill of Materials

Table 2 displays the TPS92513EVM-001 components list according to the schematic shown in Figure 1.

Table 2. TPS92513EVM-001 Components List

Ref. Designator	QTY	Value	Description	Size	Part Number	MFR
C1	1	0.1µF	CAP, CERM, 0.1µF, 25V, +/-10%, X5R	0603	06033D104KAT2A	AVX
C2, C4, C9	3	4.7uF	CAP, CERM, 4.7 µF, 100 V, +/- 10%, X7S	1210	C3225X7S2A475K200AB	TDK
C3, C6	2	0.01uF	CAP, CERM, 0.01uF, 100V, +/-10%, X7R	0603	06031C103KAT2A	AVX
C5	1	4.7uF	CAP, CERM, 4.7 µF, 25 V, +/- 10%, X7R	1206	GRM31CR71E475KA88L	Murata
C7	1	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R	0603	GCM188R71H104KA57D	Murata
C8	1	470pF	CAP, CERM, 470pF, 50V, +/-10%, X7R	0603	GRM188R71H471KA01D	Murata
D1	1	800mV @ 500mA	DIODE SCHOTTKY 80V 0.5A	SOD-123	MBR0580-TP	Micro Commercial Co
D2	1	850mV @ 2A	DIODE SCHOTTKY 80V 2A	DO-214AC, SMA	CDBA280-G	Comchip Technology
L1	1	33uH	Inductor, Shielded Drum Core, Ferrite, 33 µH, 2.6 A, 0.08 ohm	MSS1246	MSS1246-333MLB	Coilcraft
R1	1	0	RES, 0, 5%, 0.1 W	0603	CRCW06030000Z0EA	Vishay-Dale
R2	1	10.0Meg	RES, 10.0 M, 1%, 0.1 W	0603	CRCW060310M0FKEA	Vishay-Dale
R3	1	121k	RES, 121 k, 1%, 0.1 W	0603	CRCW0603121KFKEA	Vishay-Dale
R4	1	1.00k	RES, 1.00k ohm, 1%, 0.1W	0603	CRCW06031K00FKEA	Vishay-Dale
R5	1	191k	RES, 191 k, 1%, 0.1 W	0603	CRCW0603191KFKEA	Vishay-Dale
R6	1	4.02k	RES, 4.02k ohm, 1%, 0.1W	0603	CRCW06034K02FKEA	Vishay-Dale
R7	1	30.1k	RES, 30.1 k, 1%, 0.1 W	0603	CRCW060330K1FKEA	Vishay-Dale
R8	1	0.3	RES, 0.3, 1%, 1 W	2010	CSRN2010FKR300	Stackpole Electronics Inc
U1	1		TPS92513 1.5A Buck Current Regulator for High-Brightness LEDs with Integrated Analog Current Adjust	DGQ0010D	TPS92513HV	Texas Instruments

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   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

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      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

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3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
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3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should 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 also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM 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. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

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