User's Guide

TPS92200D1/D2RXLREVM User's Guide

ABSTRACT

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

Table of Contents

List of Figures

List of Tables

Trademarks

1 Introduction

The TPS92200D1/D2RXLREVM evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92200 synchronous buck switching regulator designed for high-current LED driver applications. The TPS92200 is a 1.5-A synchronous buck LED driver and features a wide input voltage range (4.0 V to 30 V), deep analog mode dimming (1% to 100%) implemented by Analog or PWM input, and PWM mode dimming capability. It also has full protection, including LED open protection and short protection, sense resistor open protection and short protection, and thermal protection.

2 Warnings and Cautions

Observe the following precautions when using the TPS92200D1/D2RXLREVM.

WARNING

When choosing an 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 TPS92200D1/D2RXLREVM provides an LED driver based on the TPS92200 buck regulator. It is designed to operate with an input voltage in the range of 4.0 V to 30 V. The EVM is set up for a default output current of 0.5 A. For TPS92200D1RXLREVM, it can work either in analog dimming mode with analog input(0.65V to 1.2V) or PWM dimming with 100Hz to 2kHz, 0-100% duty cycle PWM input. For TPS92200D2RXLREVM, it works in analog dimming mode with 20kHz to 200kHz, 0-100% duty cycle PWM input. See the TPS92200 data sheet (SLUSER4) for more information about choosing dimming mode and components selection. The forward voltage of the LED load is between approximately between 1.0 V and 30 V (depending on the input voltage). The TPS92200 helps provide high efficiency, wide dimming range, good line regulation, and low output ripple LED driver.

3.1 Typical Applications

This converter design describes an application of the TPS92200 as an LED driver using the following specifications. For applications with a different input voltage range or different output voltage and current, see the TPS92200 data sheet (SLUSER4).

Table 3-1 lists the electrical performance specifications.

Table 3-1. TPS92200D1/D2RXLREVM Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	Units
Input voltage range, V_{IN}		4.0		30	V
Output voltage range, V_{OUT}	LED+ to LED–, depends on V_{IN}	1		<30	V
Output current	3.3V, 100% duty PWM input		0.5		A
Output current ripple	V_{IN} = 24 V, 6 White LEDs, 1-A output current		10		mApp
Analog dimming range	1.2V Analog input(TPS92200D1RXLREVM)		1.2		V
Analog dimming range	3.3-V PWM amplitude, 50 kHz(TPS92200D2RXLREVM)	1		100	%
PWM dimming range	1.2-V PWM amplitude, 100 Hz, V_{IN} = 24 V, 6 White LEDs, 1-A output current(TPS92200D1RXLREVM)	1		100	%
Efficiency	V_{IN} = 12 V, 5 IR LEDs, 1.5 A output current, Analog dimming mode		96		%
Switching frequency			1000		kHz

3.2 Test Setup

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92200D1/D2RXLREVM.

3.2.1 Connector Description

Table 3-2. EVM Connectors and Test Points

Reference Designator	Function
J1	V_{IN} (see Table 3-1 for V_{IN} range)
J2	LED load, make sure the LED has a maximum 1.5-A current rating
J3	2-pin header to disable driver when no dimming required
TP1	V_{IN}test point
TP2	BOOT test point
TP3	VOUT test point, also the anode of the LED load
TP4	SW test point
TP5	AC Loop test point 1. Used for loop response measurements.
TP6	AC Loop test point 2. Used for loop response measurements.
TP7	PWM or Analog input here
TP8	GND test point for VIN
TP9	GND test point for VOUT
TP10	GND test point for PWM input
TP11	FB test point

3.2.2 Input/Output Connection

A power supply capable of supplying 2 A must be connected to J1 through a pair of 20-AWG wires. The LED load must be connected to J2 through a pair of 20-AWG wires. The positive terminal of the LED load should be connected to the J2 terminal beside TP3 (VOUT), and the negative terminal of the LED load should be connected to the J2 terminal beside TP5. Wires should be twisted and kept as short as possible to minimize voltage drop, inductance, and EMI transmission.

TP7 is the input terminals for the Analog/PWM dimming signal. For TPS92200D1RXLREVM, If analog dimming mode is used, apply a DC voltage signal between 0.65V and 1.2V. If TPS92200D1RXLREVM is used, apply a square wave with a low level of GND and a high level voltage higher than 2 V, typically 3.3 V. The PWM frequency range is 100 Hz to 2 kHz, typically 1 kHz. For TPS92200D2RXLREVM, it only supports analog dimming mode, apply a square wave with a low level of GND and a high level voltage higher than 2 V, typically 3.3 V. The dimming frequency range is 20 kHz to 200 kHz.

Once the connection is ready, first apply the input voltage, then apply the Analog/PWM signal.

4 Performance Data and Typical Characteristics Curves

The figures in this section present the typical performance of the TPS92200D1/D2RXLREVM. The ambient temperature is 25°C, unless otherwise noted.

4.1 Efficiency

Figure 4-1 shows the efficiency versus VDIM in analog dimming mode. The maximum LED current is 1.5 A when the VDIM is 1.2V. V_{IN} = 12 V, and an infrared (IR) LED load is used. The typical forward voltage of an IR LED is 1.7 V at 1.5 A. The LED number in series is 1, 3, and 5, respectively.

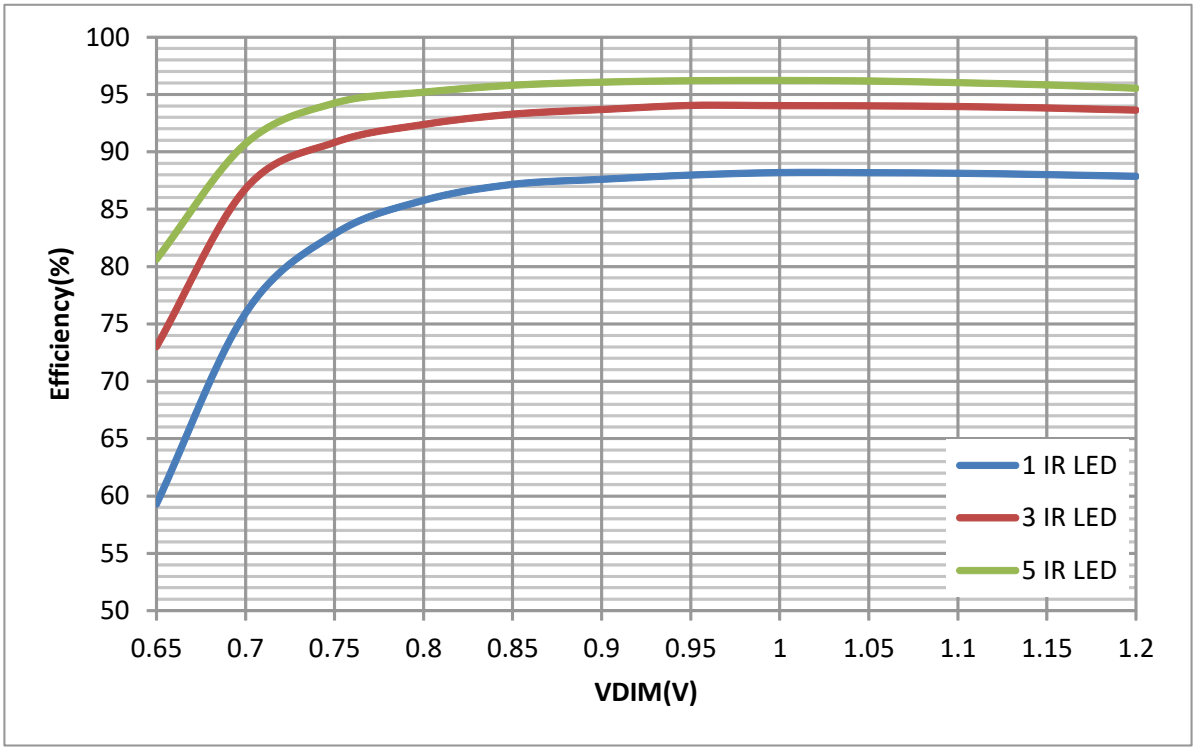

Figure 4-1. Efficiency vs. VDIM in Analog Dimming Mode(TPS92200D1RXLR), 1.5 A at VDIM>=1.2V, V_{IN} = 12 V

Figure 4-2 shows the efficiency versus PWM Duty Cycle in PWM dimming mode. PWM frequency is 500hz, LED current is set at 1.0 A. 6 White LEDs are used. The typical forward voltage of a White LED is 3 V at 1 A.

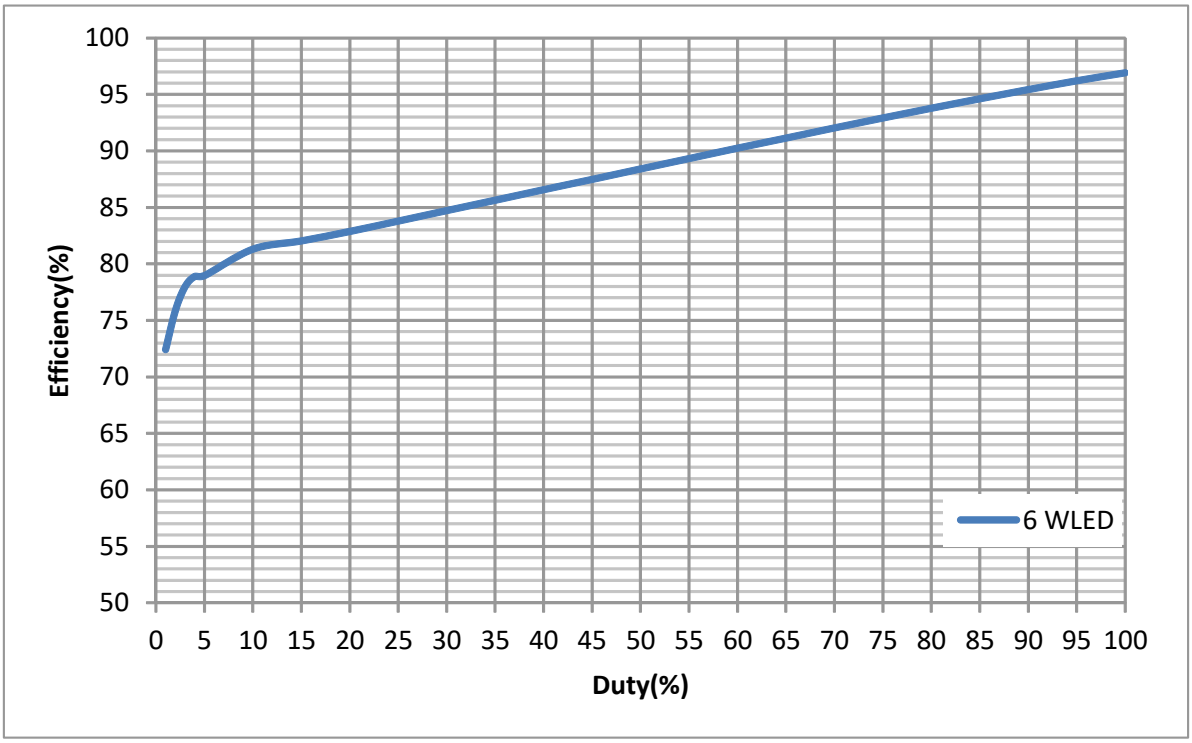

Figure 4-2. Efficiency vs. PWM Duty Cycle in PWM Dimming Mode(TPS92200D1RXLR), 1.0 A at 100% Duty

Figure 4-3 shows the efficiency versus PWM Duty Cycle in Analog dimming mode. PWM frequency is 50khz, LED current is set at 1.0 A. two IR LEDs are used. The typical forward voltage of a White LED is 1.65 V at 1 A.

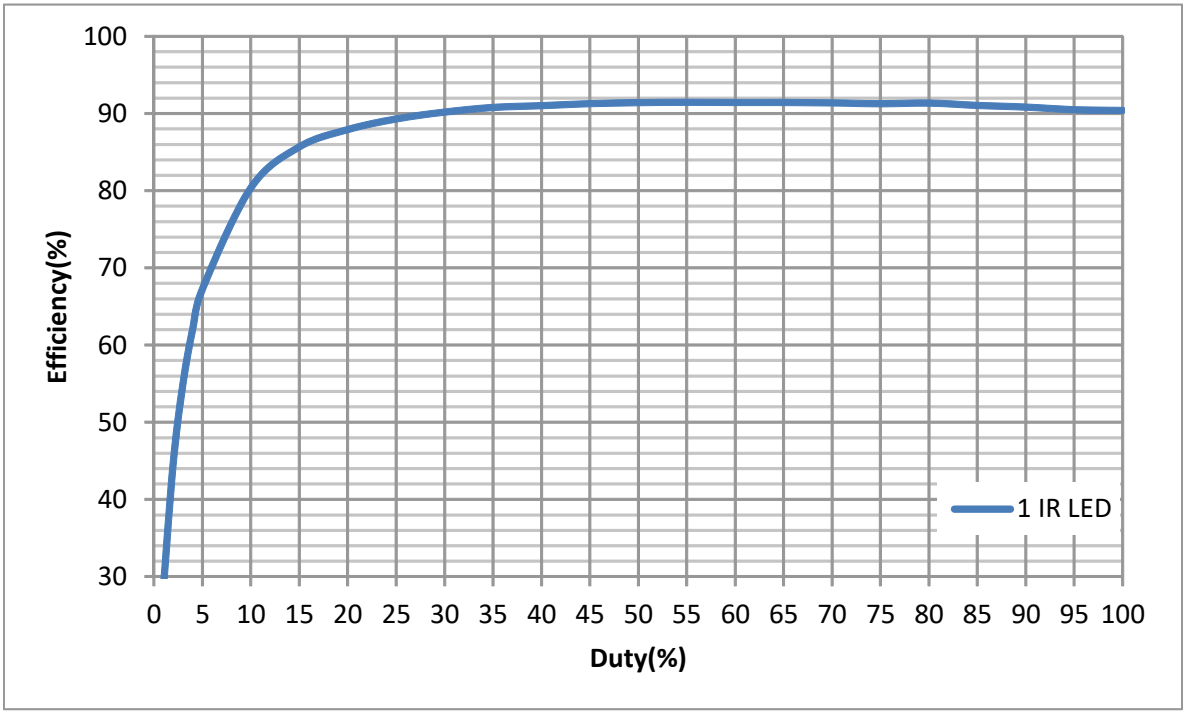

Figure 4-3. Efficiency vs. PWM Duty Cycle in Analog Dimming Mode(TPS92200D2RXLR)

4.2 Line Regulation

Figure 4-4 shows the output current deviation ratio vs. input voltage in analog dimming mode. VDIM is 1.2V. 1 White LED is used as load. The LED current is set at 250mA, 500mA, 1.0A and 1.5A, respectively. The typical forward voltage of the White LED is 3.1 V at 1.5 A, and 2.8 V at 0.35 A.

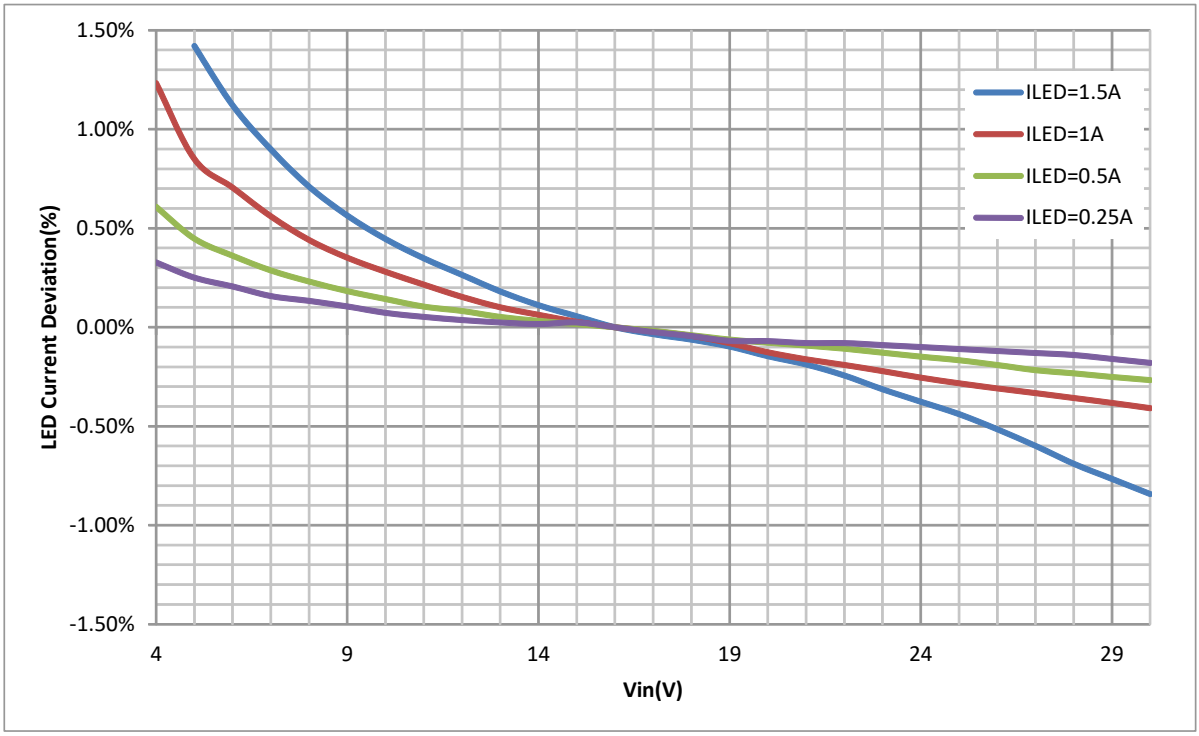

Figure 4-4. LED Current Deviation vs. Input Voltage in Analog Dimming Mode, 1 WLED

4.3 Load Regulation

Figure 4-5 shows the output current deviation ratio vs. output voltage in analog dimming mode. VDIM is 1.2V. White LEDs are used as load, LED number in series is 1, 2, 3, 4, 5, and 6, respectively. LED current is set at 250mA, 500mA, 1.0A and 1.5A, respectively. The typical forward voltage of the White LED is 3.1 V at 1.5 A, and 2.8 V at 0.35 A. Changing the LED number in series from 1 piece to 6 pieces will change the output voltage from approximately 3 V to approximately 18 V. Input voltage is fixed at 24 V.

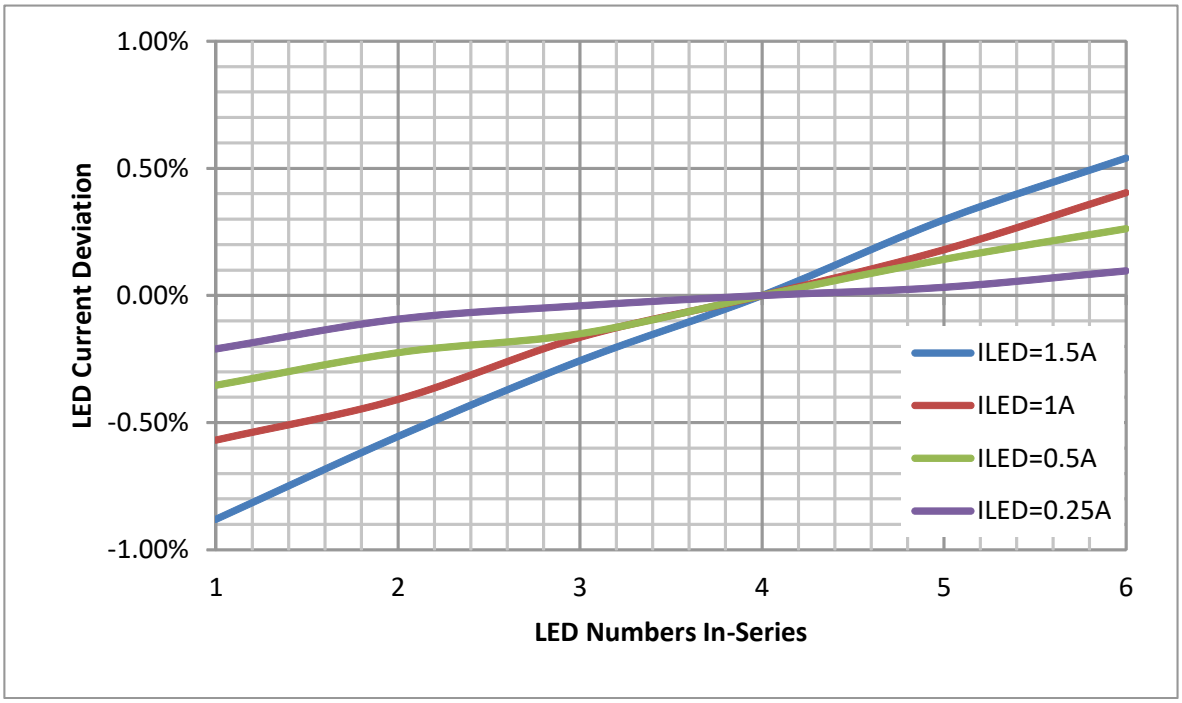

Figure 4-5. LED Current Deviation vs. LED Numbers in Series in Analog Dimming Mode, V_{IN} = 24 V

4.4 Analog Dimming

Figure 4-6 shows the output current ratio to the full-scale output current versus VDIM voltage level in analog dimming mode. V_{IN} = 12 V, 1 White LED is used as load. The LED current is set at 1.0 A with VDIM=1.2V.

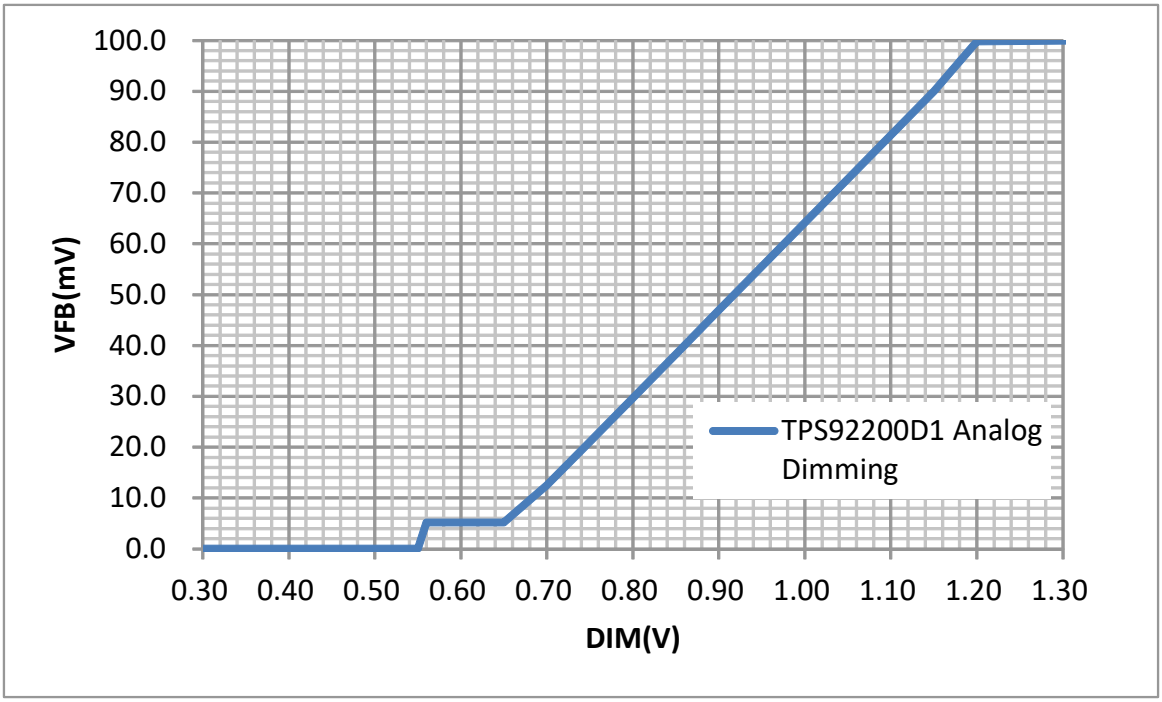

Figure 4-6. Output Current Ratio vs. VDIM in Analog Dimming Mode(TPS92200D1RXLR)

Figure 4-7 shows the output current ratio to the full-scale output current versus PWM duty cycle in analog dimming mode. V_{IN} = 12 V, 2 White LEDs in series used as load. The LED current is set at 1.0 A with 100% PWM duty. PWM frequency is 50 kHz.

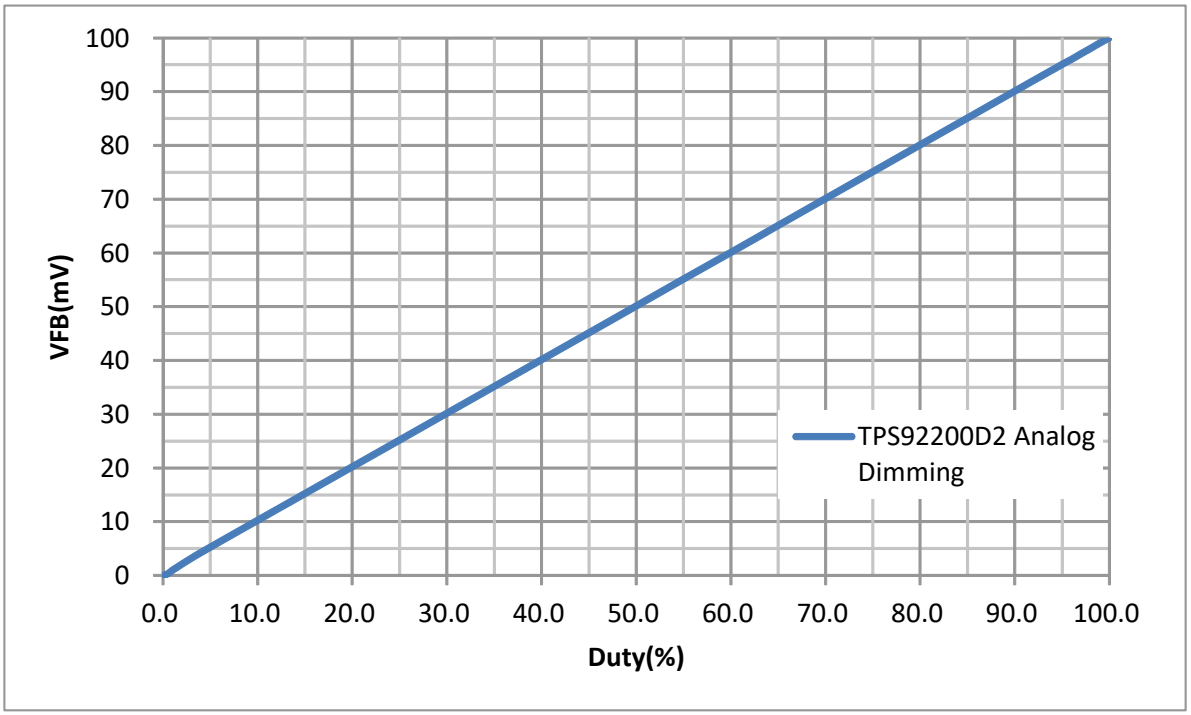

Figure 4-7. Output Current ratio vs PWM Duty Cycle in Analog Dimming Mode(TPS92200D2RXLR)

4.5 PWM Dimming Waveforms

Figure 4-8, Figure 4-9, and Figure 4-10 illustrate the PWM dimming waveforms at 1%, 50%, and 95% duty cycles, respectively, in PWM dimming mode. Input voltage is 24 V, with 6 White LEDs in series used as load. The LED current is set at 1.0 A, PWM frequency is 100 Hz.

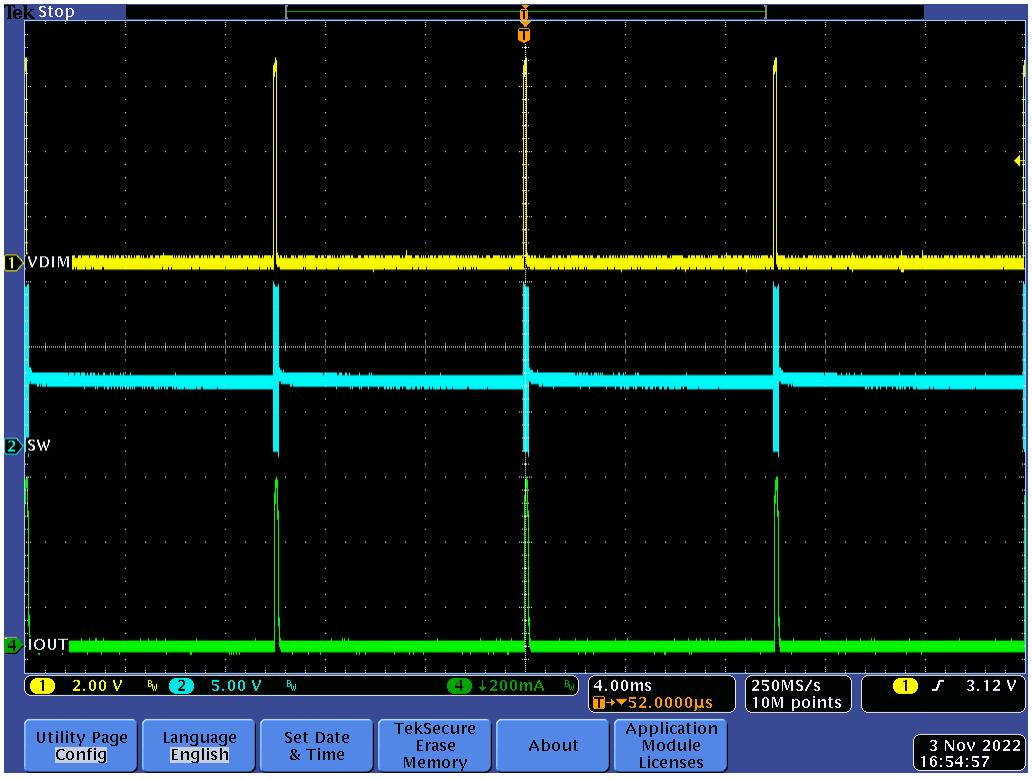

Figure 4-8. 1% Duty Cycle 100-Hz PWM Dimming(TPS92200D1RXLR)

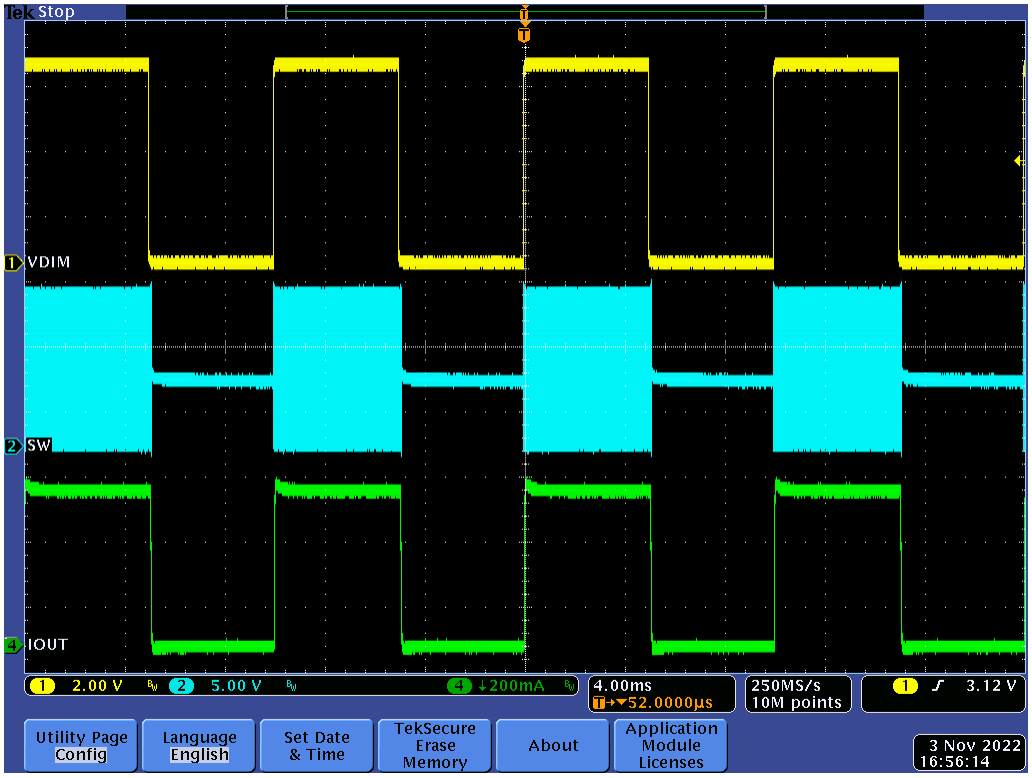

Figure 4-9. 50% Duty Cycle 100-Hz PWM Dimming(TPS92200D1RXLR)

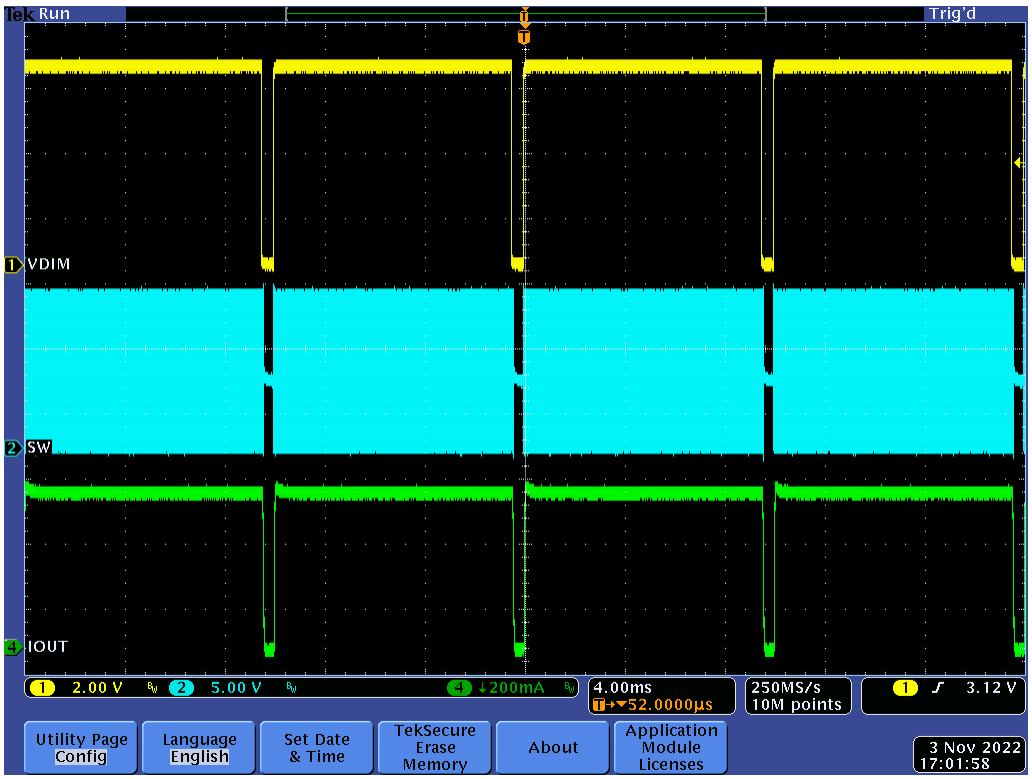

Figure 4-10. 95% Duty Cycle 100-Hz PWM Dimming(TPS92200D1RXLR)

5 Schematic

Figure 5-1 displays the TPS92200D1RXLREVM schematic.

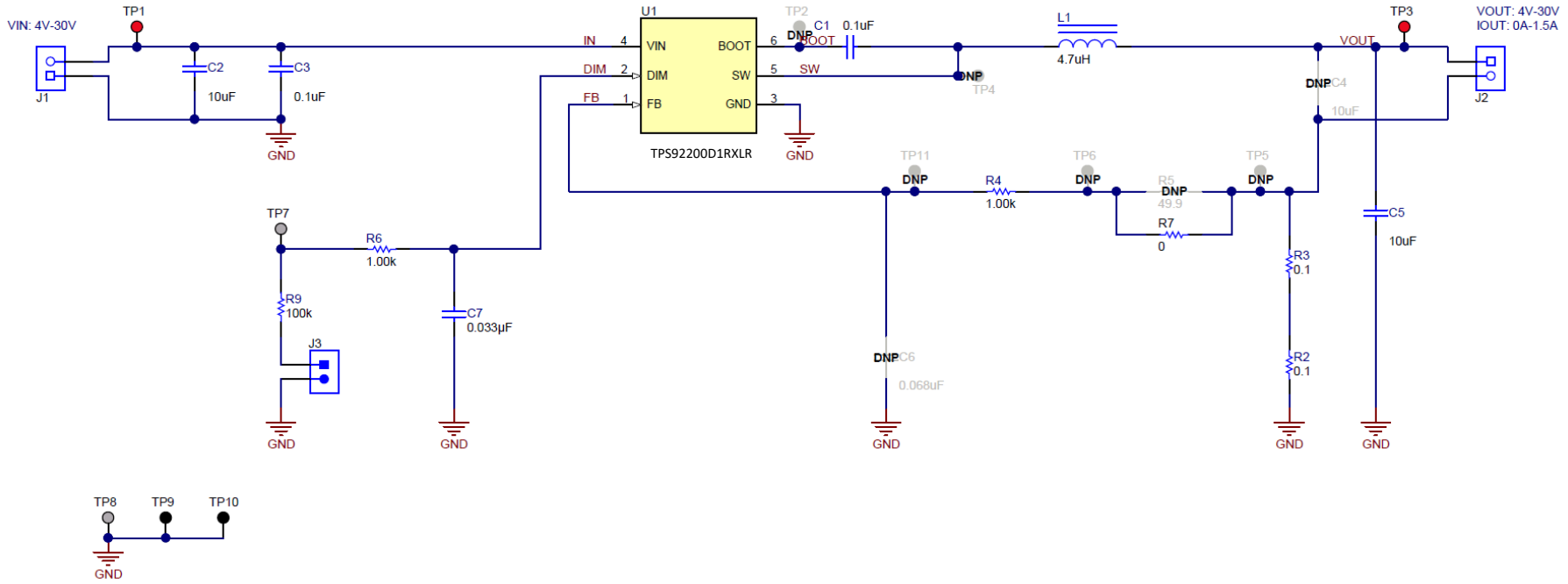

Figure 5-1. TPS92200D1RXLREVM Schematic

Figure 5-2 displays the TPS92200D2RXLREVM schematic.

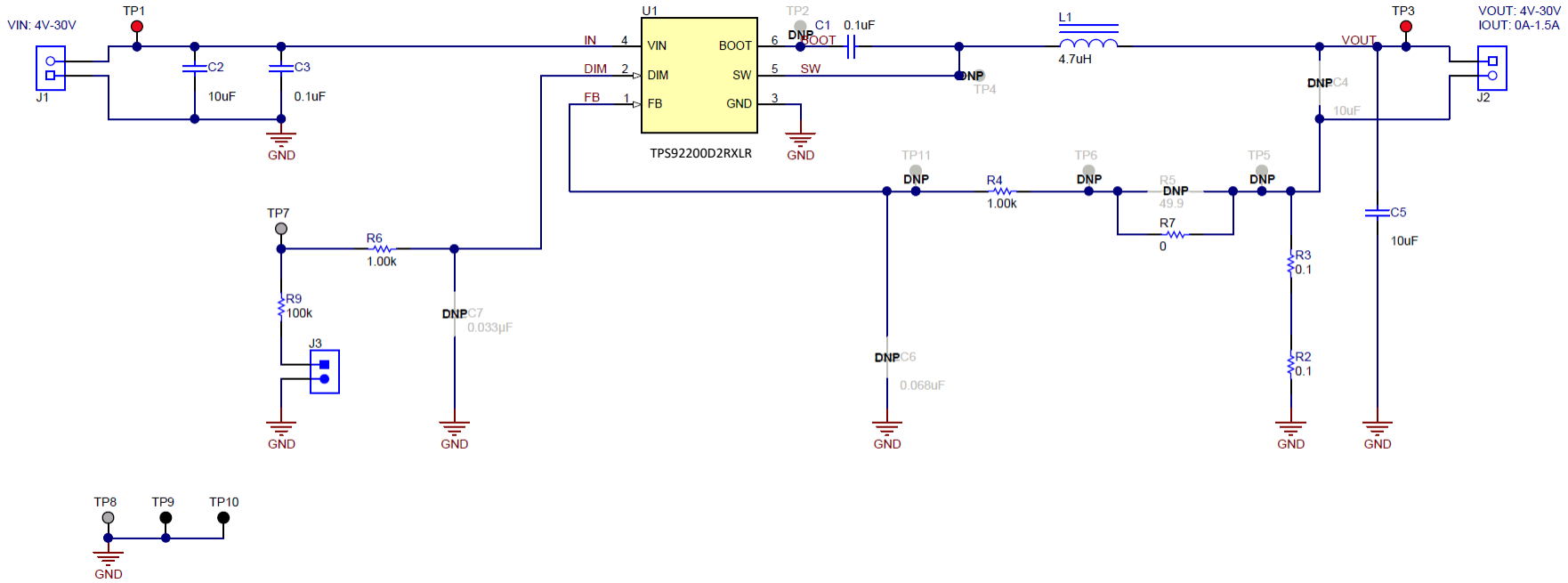

Figure 5-2. TPS92200D2RXLREVM Schematic

6 TPS92200EVM PCB Layout

Figure 6-1 and Figure 6-2 show the design of the TPS92200EVM printed-circuit board.

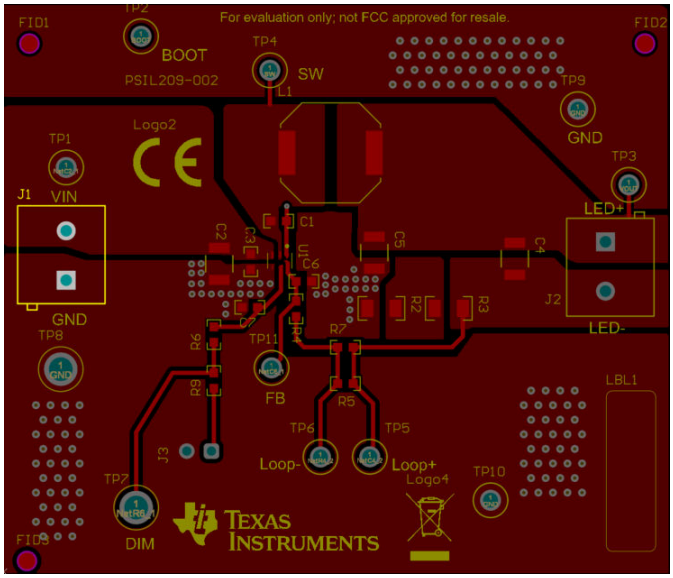

Figure 6-1. Top Layer and Top Overlay (Top View)

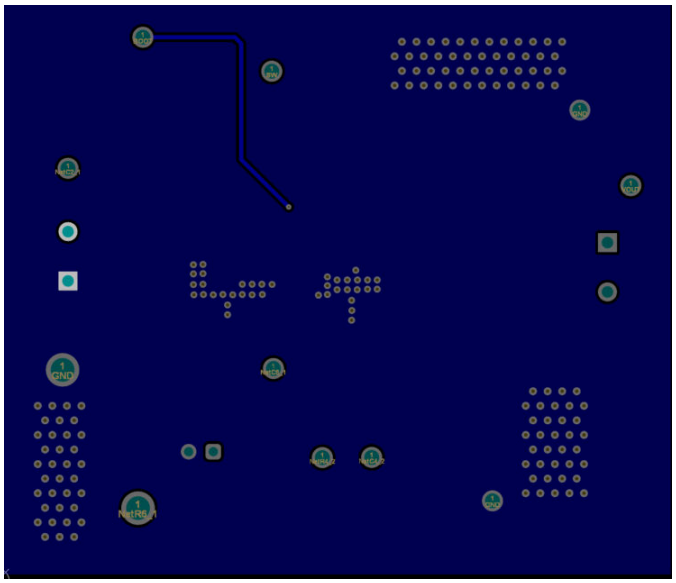

Figure 6-2. Bottom Layer and Bottom Overlay (Bottom View)

7 Bill of Materials

Table 7-1 displays the TPS92200EVM components list according to the schematic in Figure 5-1.

Table 7-1. TPS92200EVM Components List

Designator	Qty	Value	Description	Package	Part Number	Manufacturer
C1, C3	2	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603	0603	06035C104KAT2A	AVX
C2, C5	2	10uF	CAP, CERM, 10 µF, 35 V, +/- 10%, X7R, AEC-Q200 Grade 1, 1210	1210	CGA6P3X7S1H106K250AB	TDK
C7	1	0.033uF	CAP, CERM, 0.033 µF, 16 V, +/- 10%, X7R, 0603(TPS92200D1EVM Only)	0603	CL10B333KO8NNNC	Samsung Electro-Mechanics
J1, J2	2		Terminal Block, 5.08 mm, 2x1, Brass, TH	2x1 5.08 mm Terminal Block	ED120/2DS	On-Shore Technology
J3	1		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec
L1	1	4.7uH	Inductor, Shielded Drum Core, Ferrite, 4.7 µH, 4.2 A, 0.02 ohm, SMD	WE-TPC-XLH2	7440650047	Wurth Elektronik
R7	1	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R2, R3	0.1	0.1	RES, 0.1, 1%, 0.5W, 1206	1206	CSR1206FKR100	Stackpole Electronics Inc
R4, R6	2	1.00k	RES, 1.00k, 0.5%, 0.1 W, 0603	0603	RT0603DRE071KL	Yageo America
R9	1	100k	RES, 100 k, 0.1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERA-3AEB104V	Panasonic
TP1, TP3	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP7, TP8	2		Terminal, Turret, TH, Double	Keystone1502-2	1502-2	Keystone
TP2, TP4, TP5	3		Test Point, Multipurpose, White, TH	Keystone5012	5012	Keystone
TP6, TP9, TP10, TP11	4		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
U1	1		4.0V TO 30V INPUT VOLTAGE, 1.5 A OUTPUT CURRENT, SYNCHRONOUS BUCK LED DRIVER WITH FLEXIABLE DIMMING OPTIONS	VQFN-HR(6)	TPS92200D1RXLR(TPS92200D1RXLREVM) / TPS92200D2RXLR(TPS92200D2RXLREVM)	Texas Instruments

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, 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.

WARNING

Evaluation Kits 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 shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

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

FCC NOTICE: 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 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. 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

3.3 *Japan*

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。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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 to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

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.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265