User's Guide

TPS92643-Q1 Evaluation Module User's Guide

ABSTRACT

This user's guide describes the characteristics, operation, and use of the TPS92643-Q1 3-A synchronous high current buck LED driver evaluation module (EVM). A complete schematic diagram, printed-circuit board layouts, and bill of materials are included in this document.

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Trademarks

All trademarks are the property of their respective owners.

1 Introduction

The TPS92643EVM-204 evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92643-Q1 3.0-A buck switching regulator designed for high-current LED drive applications. The TPS92643-Q1 is designed to control high-brightness light-emitting diodes (LED) and features a wide input voltage range (5.5 V to 40 V), PWM dimming capability, analog dimming capability, input undervoltage lockout protection, fault detection, an internal 5-V regulator, and the ability to perform duty cycle control of the on-board, 1.6-kHz PMW signal.

2 Warnings and Cautions

Observe the following precautions when using the TPS92643EVM-204.

CAUTION

Caution! Do not leave EVM powered when unattended.

HOT SURFACE:

Caution Hot Surface! Contact may cause burns. Do not touch. Please take the proper precautions when operating.

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 eye wear and be fully aware of surrounding laboratory-type set-ups when viewing intense light sources that can be required to minimize or eliminate such risks in order to avoid accidents related to temporary blindness.

3 Description

This user's guide describes the specifications, board connection descriptions, characteristics, operation, and use of the TPS92643-Q1, 3.0-A synchronous buck LED driver evaluation module (TPS92643EVM-204). The TPS92643-Q1 device implements an adaptive on-time average current mode control and is designed to be compatible with shunt FET dimming techniques and LED matrix manager-based dynamic beam headlamps. The adaptive on-time control provides near constant switching frequency that can be set from 100 kHz to 2.2 MHz. Inductor current sensing and closed-loop feedback enables better than ±4% accuracy over wide input voltage, output voltage and ambient temperature range.

TPS92643EVM-204 provides a high-brightness LED driver that is designed to operate with an input voltage in the range of 5.5 V to 36 V (nominally at 14 V). The EVM is setup for a default output current of 2.5 A (programmable to 3 A) for an LED stack between approximately 3 V and nearly 32 V operating at 440 kHz. The TPS92643-Q1 helps provide high efficiency, fast PWM dimming, and accurate wide-range analog dimming.

3.1 Typical Applications

This converter design describes an application of the TPS92643-Q1 as an LED driver with the specifications listed in Table 3-3. For applications with a different input voltage range or different output voltage range, refer to the *TPS92643-Q1 Automotive 3-A Synchronous Buck LED Driver* data sheet.

3.2 Features

- AEC-Q100 qualified for automotive applications
  - Grade 1: –40°C to 125°C ambient operating temperature
  - Device HBM classification level H1C
  - Device CDM classification level C2
- Cycle-by-cycle switch overcurrent protection
- Nominal switching frequency
  - 440 kHz
- 5.5-V to 40-V wide input voltage range
- Adaptive on-time average current control
- LED open and short fault monitoring and reporting
- Switch thermal protection
- Advanced dimming operation
  - Precision analog dimming
  - Supports external PWM dimming input

3.3 Connector and Test Point Description

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92643EVM-204.

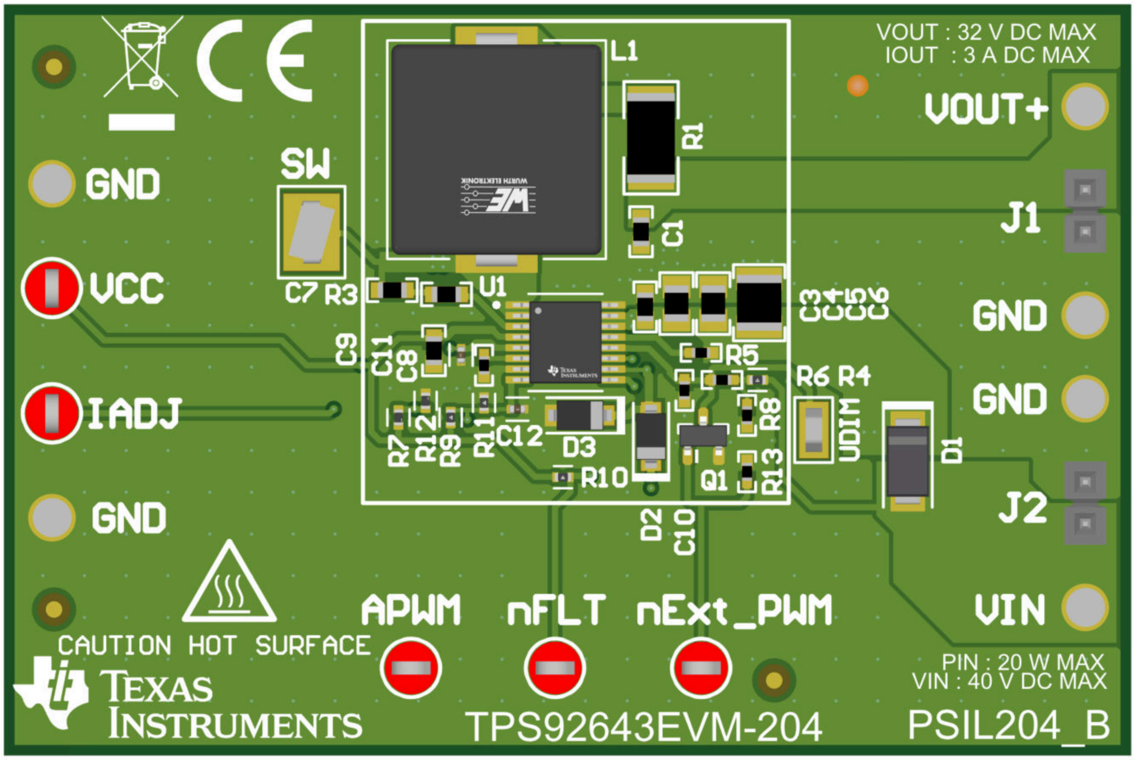


Figure 3-1. TPS92643EVM-204 Top View – EVM Functions and Features

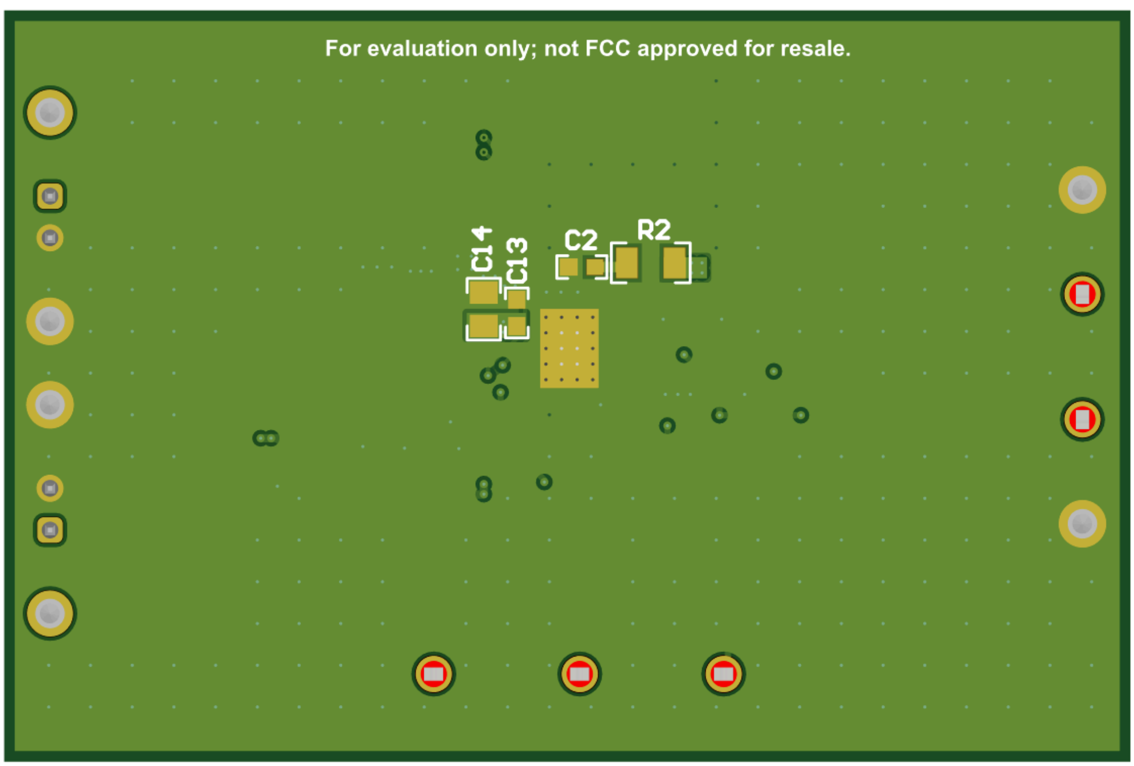


Figure 3-2. TPS92643EVM-204 Bottom View – EVM Functions and Features

This section describes the connectors, names, and descriptions.

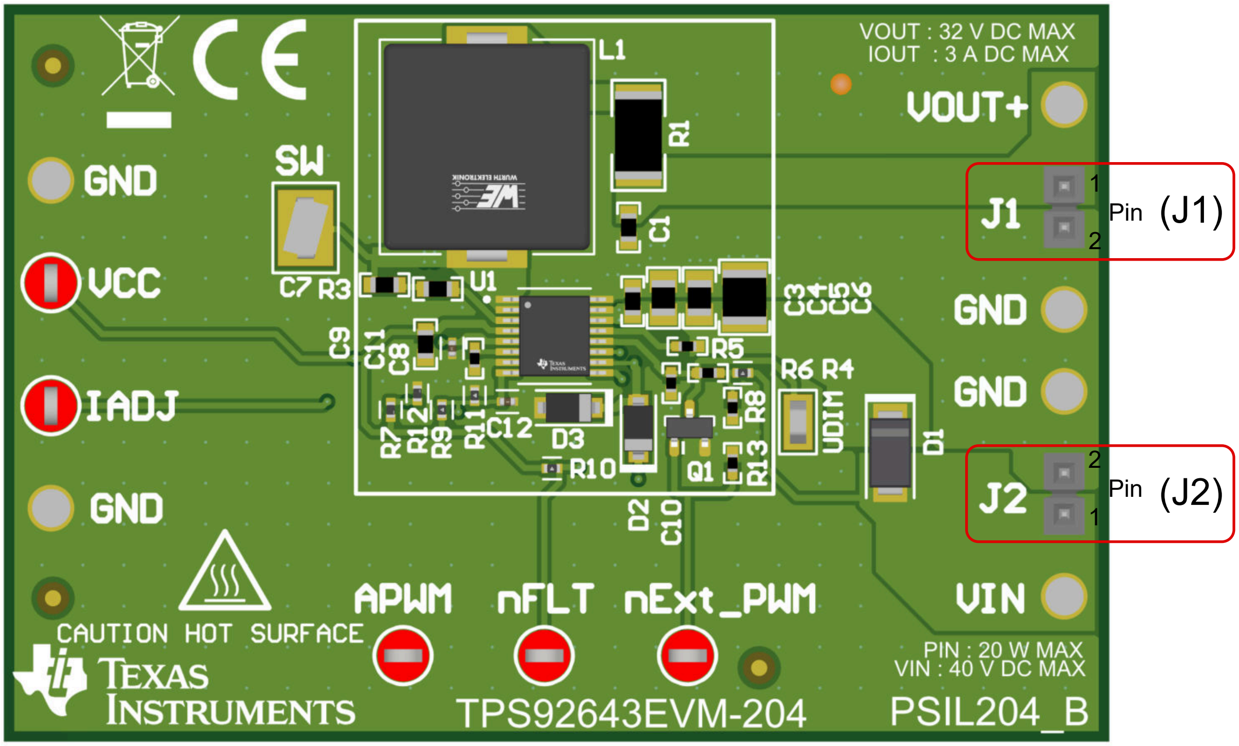


Figure 3-3. TPS92643EVM-204 Connector Numbers and Locations

Table 3-1. Connectors

Connector	Description
J1	J1 allows for a creating a harness that connector to VOUT+ (pin 1) and GND (pin 2).
J2	J2 allows for a creating a harness that connector to VIN (pin 1) and GND (pin 2).

This section describes the test points, names, and descriptions.

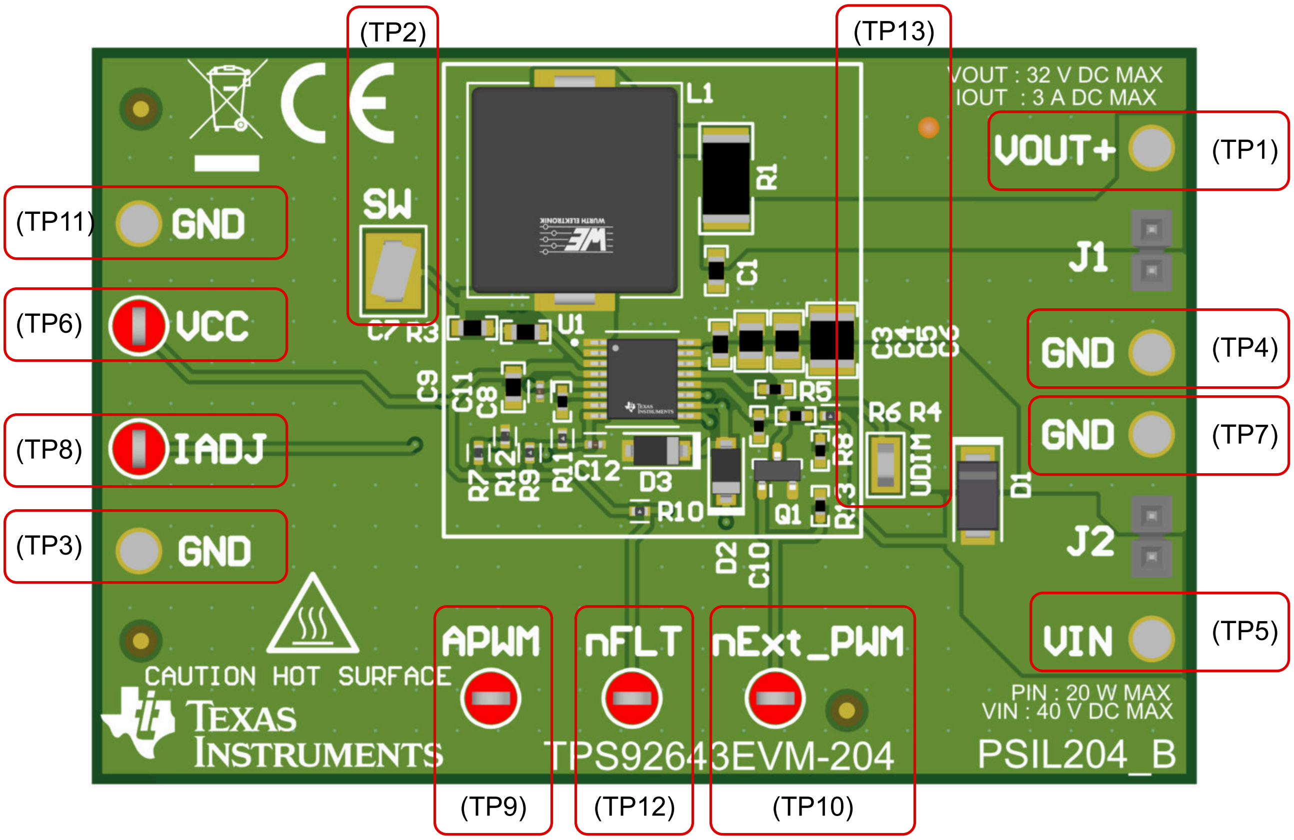


Figure 3-4. TPS92643EVM-204 Test point Numbers and Locations

Table 3-2. Test Points

Test Point	Description
GND (TP3, TP4, TP7, TP11)	Larger metal turrets and test points allow for multiple connection to grounds across the board.
VIN (TP5)	The VIN test point allows for voltage and current measurement of the power applied to the VIN pin of the TPS92643-Q1.
VCC (TP6)	The VCC test point is connected to TPS92643's internal 5-V linear supply output.
VOUT+ (TP1)	The VOUT+ test point allows for connection of the LED loads to the output. Large turrets allow for multiple connections.
SW (TP2)	The SW test point allows for observing the switch node for the output during operation with an oscilloscope.

Table 3-2. Test Points (continued)

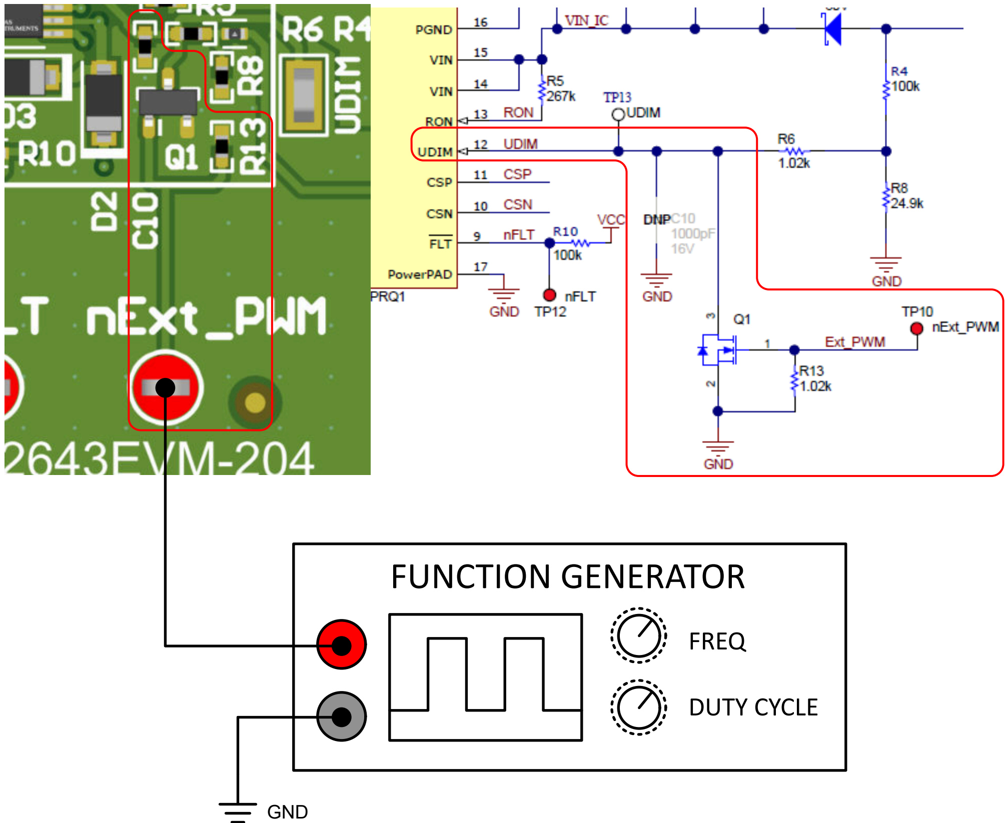
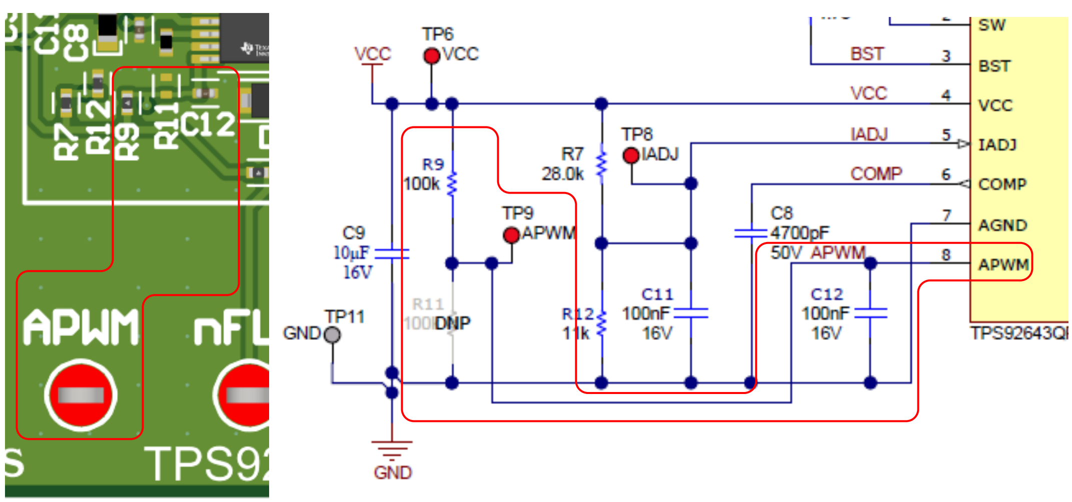
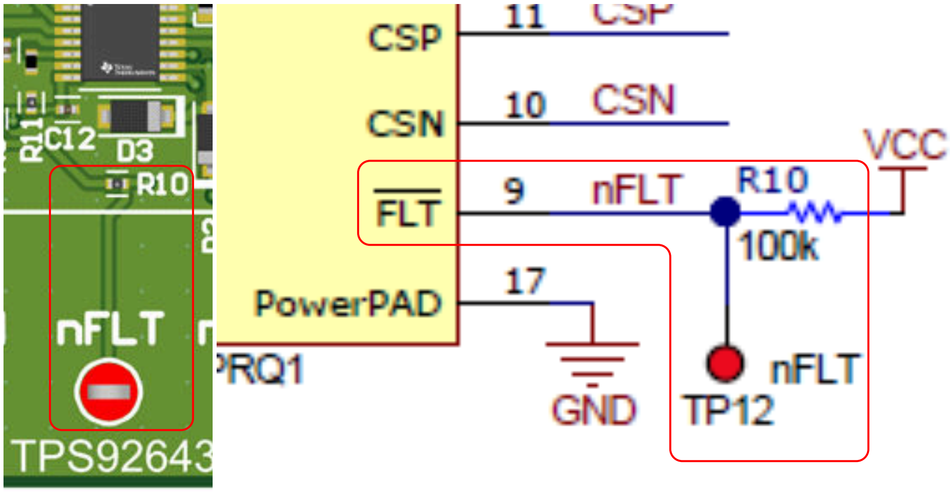
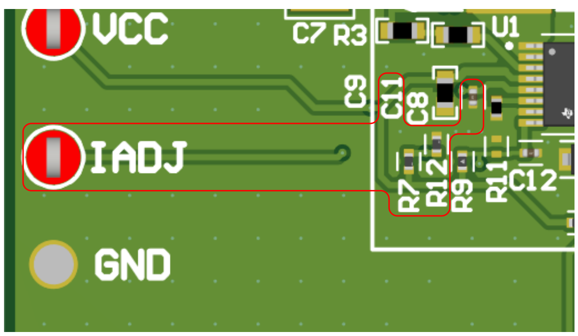
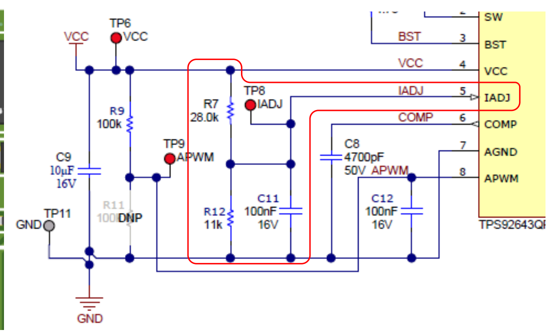
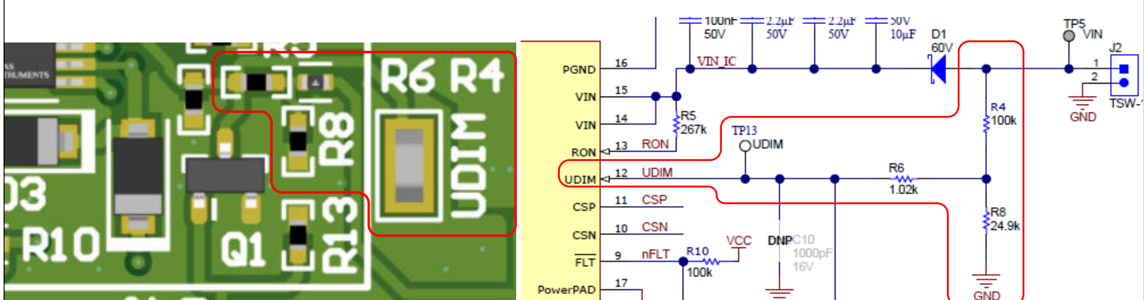
Test Point	Description
nExt_PWM (TP10)	nExt_PWM test point allows for the indirect connection of the UDIM pin through the use of a N-FET (Q1) on the UDIM pin of the TPS92643-Q1 for PWM dimming of the output. UDIM (TP13) is inverted from the nExt_PWM signal. Read the External PWM Dimming and Input Undervoltage Lockout (UVLO) section in the *TPS92643-Q1 Automotive 3-A Synchronous Buck LED Driver* data sheet for additional information. 
APWM (TP9)	This test point is the test point used to perform analog duty cycle control of the 1.6-kHz PWM output. The APWM pin is by default pulled to 5 V, which means it is at 100% duty cycle. The duty cycle starts from 1 V and 0% duty cycle and goes to 2.5 V which is 100% duty cycle. For example, 1.75 V is 50% duty cycle of the 1.6-kHz PWM signal. 

Table 3-2. Test Points (continued)

Test Point	Description
nFLT (TP12)	The nFLT test point can be used to monitor if a fault has occurrence on the TPS92643-Q1 output. When a fault occurs, nFLT voltage level goes low. Read the Faults and Diagnostics section of the *TPS92643-Q1 Automotive 3-A Synchronous Buck LED Driver* data sheet to determine which faults trigger the nFLT indication. 
IADJ (TP8)	The TPS92643-Q1's LED current are controlled by applying a voltage to the IADJ test point. 133 mV to 2.45 V for VIADJ gives 190 mA to 3000 mA of output current. 
UDIM (TP13)	UDIM is the undervoltage lockout and PWM input. Connecting VIN through a resistor divider to implement input undervoltage protection. Diode, N-FET, or NPN couple signal to enable dimming. 

3.4 Electrical Performance Specifications

Table 3-3 lists the EVM electrical performance specifications. This configuration is designed for driving up to 3 A to 1-3 LEDs with an input voltage range of 10 V to 36V. This configuration is also designed to operate at approximately 400 kHz for optimized efficiency. The device can operate at lower input voltage, but this EVM is setup to meet the following parameters.

Table 3-3. TPS92643EVM-204 Performance Specifications

Parameter	Description	Min	Typ	Max	Units
Input Characteristics					
Voltage, V_{IN}		10	14	36	V
Maximum input current, I_{IN}				4.0	A
Output Characteristics					
Output voltage, V_{OUT}	This EVM was tested with 1 to 3 LEDs that had a voltage range of 2.5 V to 9.5 V for a current range of 0.2 A to 3.0 A.	V_{IN}		30	V
Maximum output current, I_{OUT}	Total output current is designed for 0.2 A to 3.0 A.			3.0	A
Maximum output power, P_{OUT}	Total output power			20	W
Systems Characteristics					
Switching frequency	R_{ON} = 267 k Ohms		440		kHz
Peak efficiency				96	%
Operating temperature	NOTE: Maximum temperature range is based on total power dissipation.	–40	25	125	°C

4 Test Setup

The TPS92643EVM-204 can be connected a variety of different ways. Figure 4-1 shows a typical test setup.

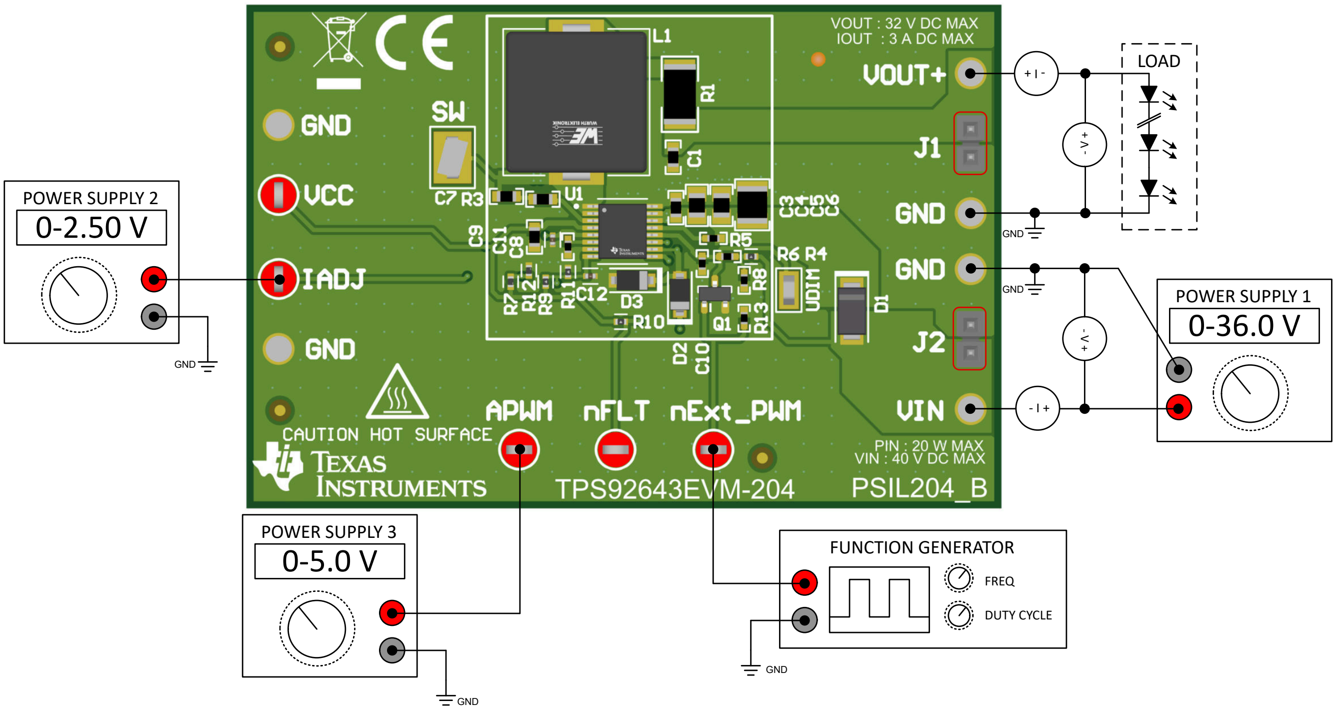


Figure 4-1. TPS92643EVM-204 Typical Test Setup

4.1 Input Supplies and LED Load Connections

The LEDs are to be connected, as shown in Figure 4-2, where the anode of the LEDs are to be connected to VOUT+ test points or through J1 or VOUT+ (TP1) and the cathode of the LEDs to GND (TP4). The input power supply can be connected by header J2 using a harness or by VIN (TP5) and GND (TP7) using test cables.

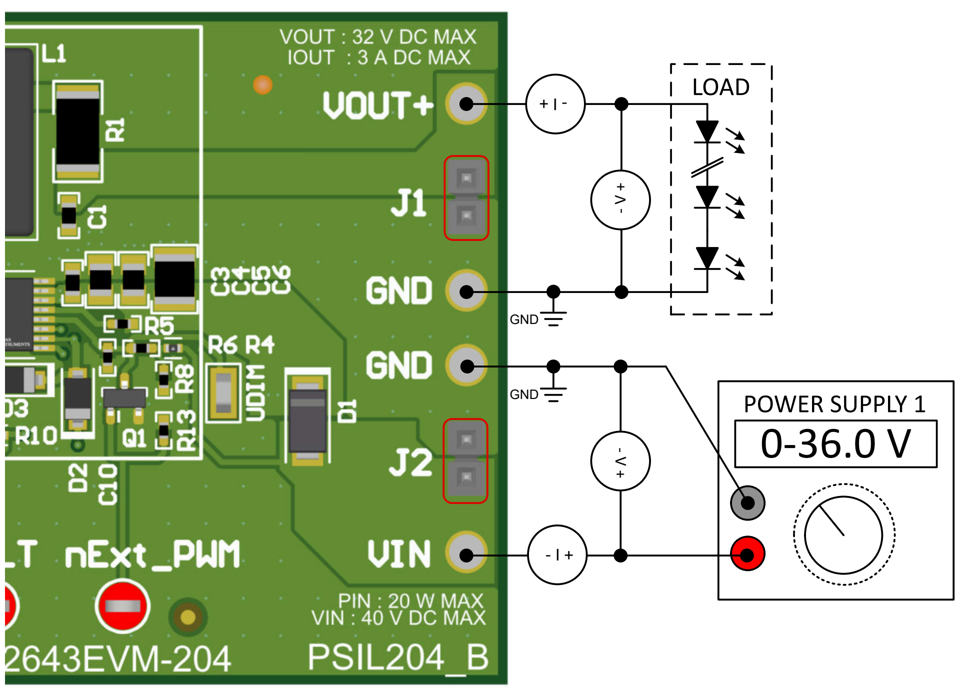


Figure 4-2. VIN and VOUT+ (LED) Connections

4.2 Analog Duty Cycle Control Using APWM

The TPS92643EVM-204 is by default setup without APM. Testing the analog duty cycle control is performed by applying a power supply to APWM test pin (TP9). The duty cycle is at the minimum at 1 V (0% duty cycle) and linearly increased until 2.5 V (100% duty cycle). For example, if APWM is set to 1.75 V, then the duty cycle is set to 50%. The PWM frequency is 1.6 kHz.

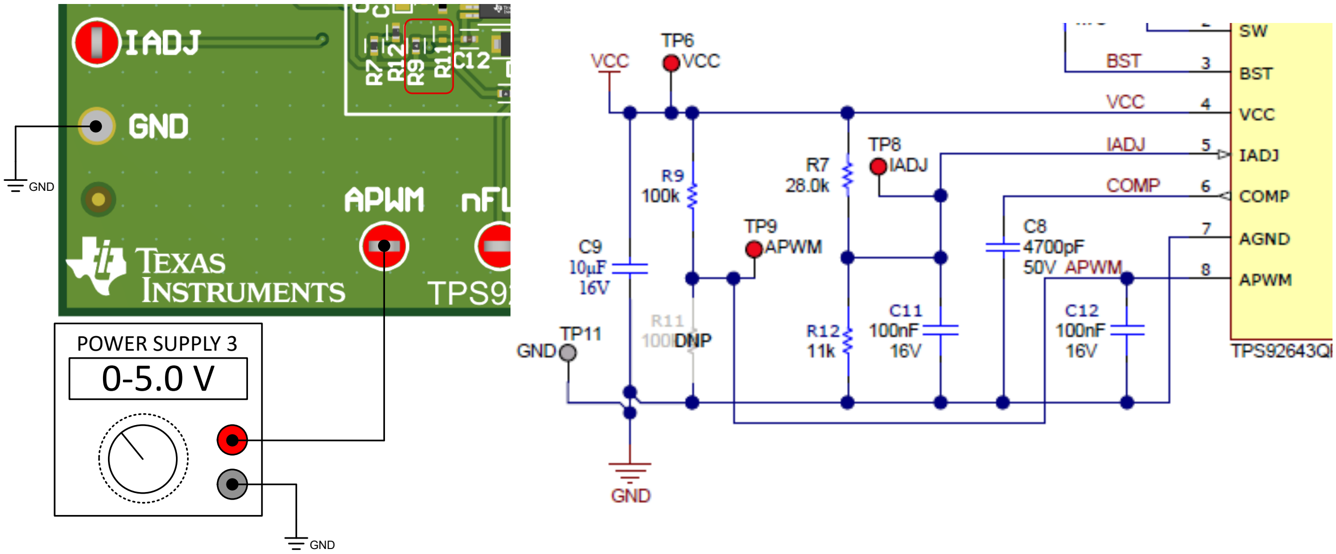


Figure 4-3. Test Setup for APWM

4.3 Analog Dimming Using IADJ

Analog Dimming is controlled by IADJ (TP8) test point or by using the resistor divider attached to VCC. The voltage on the IADJ pin sets the regulated LED current by the following equation.

$$I_{LED} = \frac{V_{IADJ}}{14 \times R_{CS}} \quad (1)$$

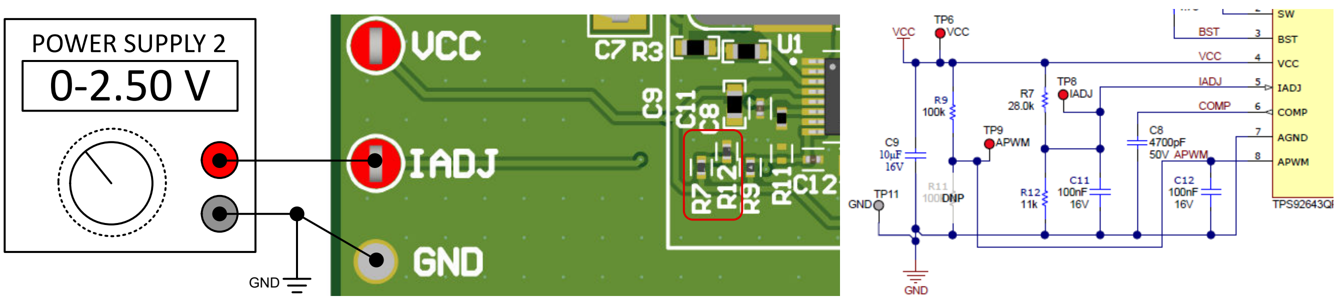


Figure 4-4. IADJ Using External Supply

There is a placeholder for resistor divider and R_{FB2} (R7) and R_{FB1} (R12) has to be calculated for the desired I_{LED}. See Figure 4-5 and Equation 2 for the circuit diagram and equation. The voltage on IADJ (TP8) controls the output current. See Figure 4-6.

$$I_{LEDx} = \frac{V_{IADJ}}{14 \times R_{CS}} = \frac{V_{CC}}{14 \times R_{CS}} \times \frac{R_{FB1}}{(R_{FB1} + R_{FB2})} \quad (2)$$

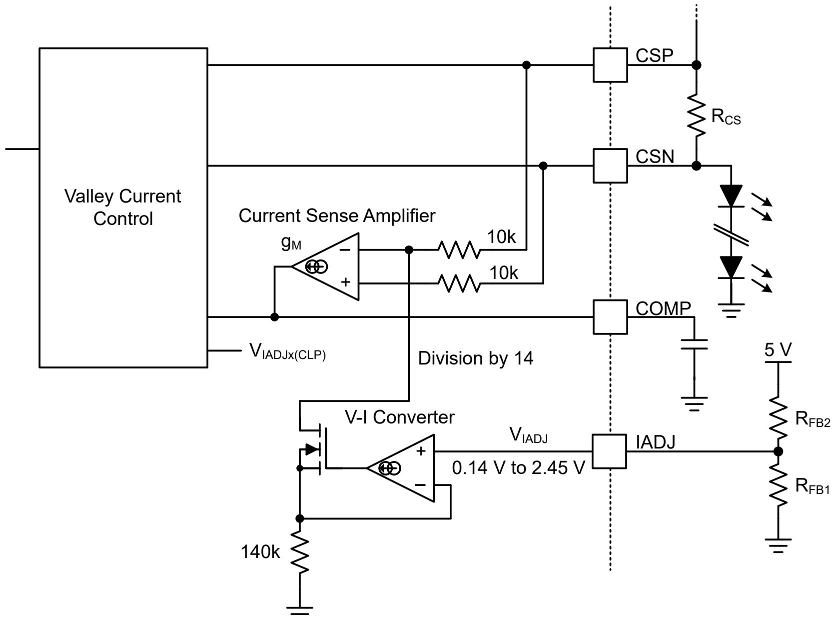


Figure 4-5. Setting IADJ Using On-Board Resistor Divider

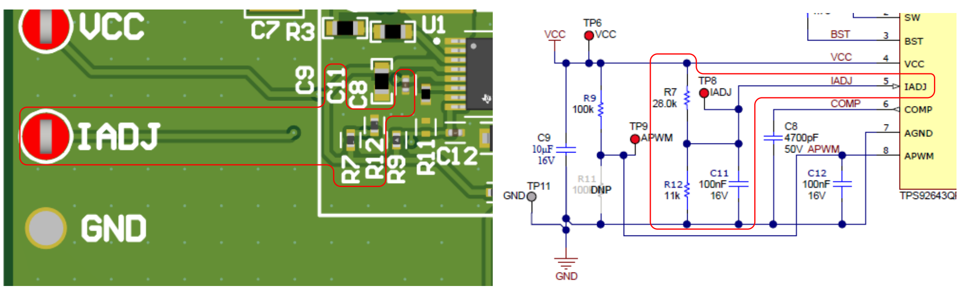


Figure 4-6. IADJ Using Resistor Divider

4.4 PWM Dimming Using nExt_PWM Test Points

PWM dimming can be achieved by the nExt_PWM test point. UDIM has a resistor divider that sets up the UVLO from VIN (Figure 4-7). The nExt_PWM signal inverts the signal to UDIM.

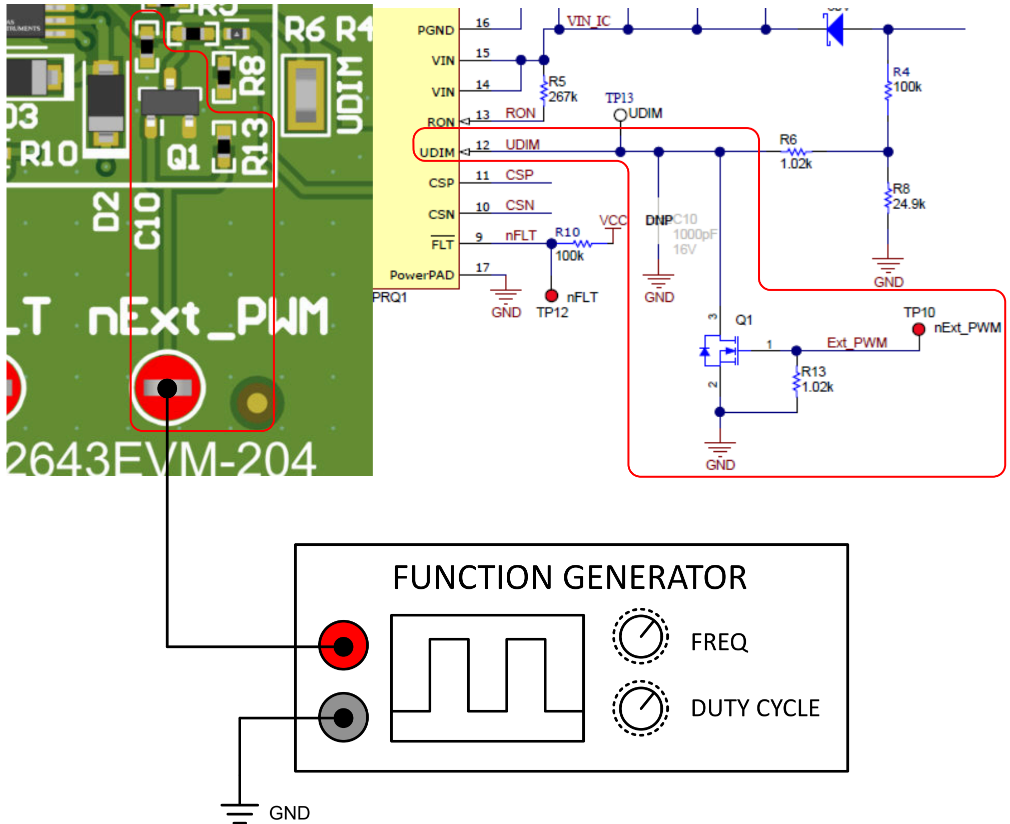


Figure 4-7. PWM Dimming Using nExt_PWM

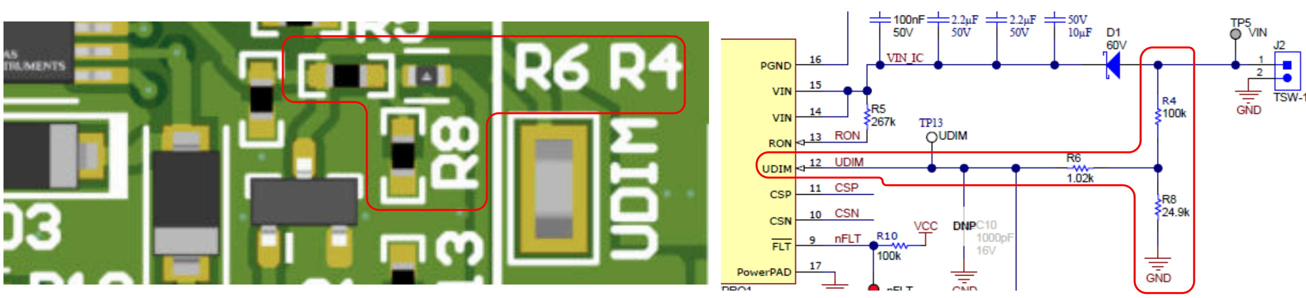


Figure 4-8. UVLO using UDIM

4.5 Switching Frequency Set Point Using RON

The TPS92643EVM-204 is by default setup for a switching frequency of 440 kHz. If a switching frequency between 100-kHz and 2.1-MHz operation is desired, then both the inductors (L1) and R_{ON} (R5) must be changed. See *TPS92643-Q1 Automotive 3-A Synchronous Buck LED Driver* data sheet for more details for the design calculations.

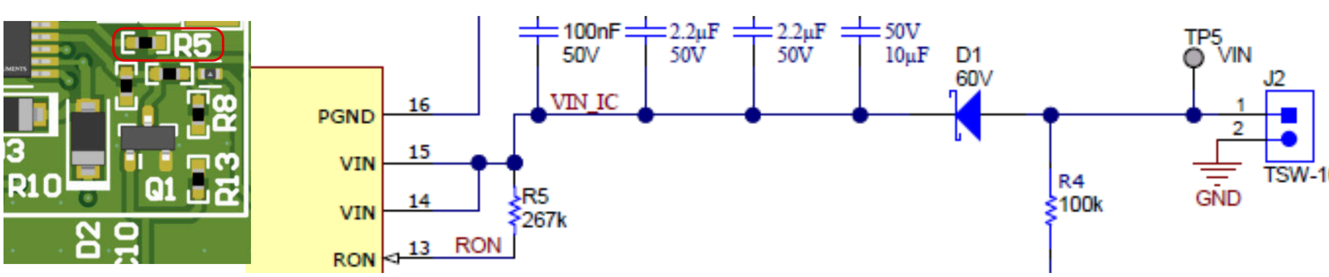


Figure 4-9. Switching Frequency Selection Based on RON (R5)

5 Performance Data and Typical Characteristic Curves

Figure 5-1 through Figure 5-6 present typical performance curves for TPS92643EVM-204.

5.1 Efficiency

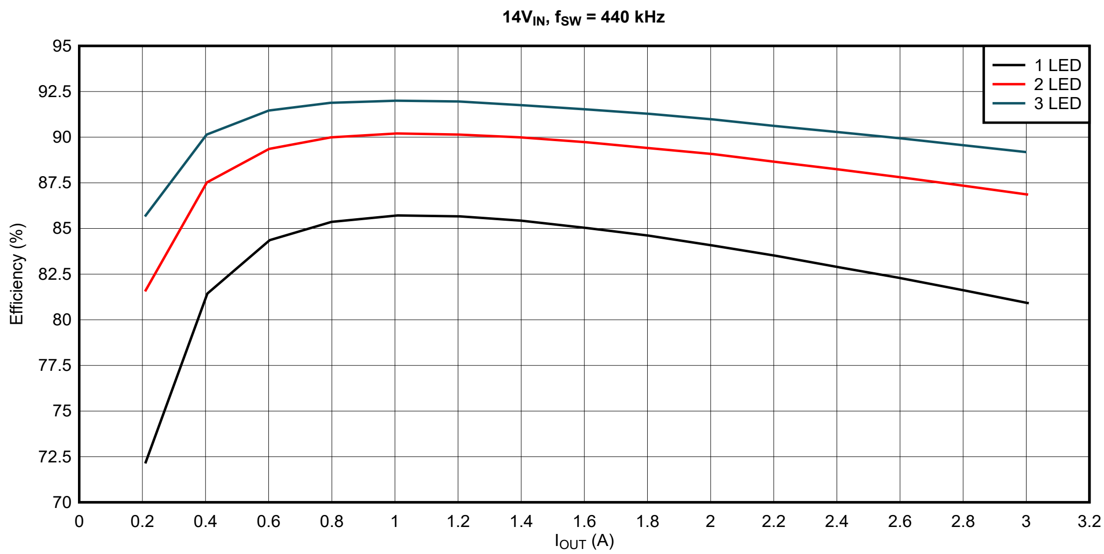


Figure 5-1. Efficiency vs Output Current

5.2 Analog Dimming

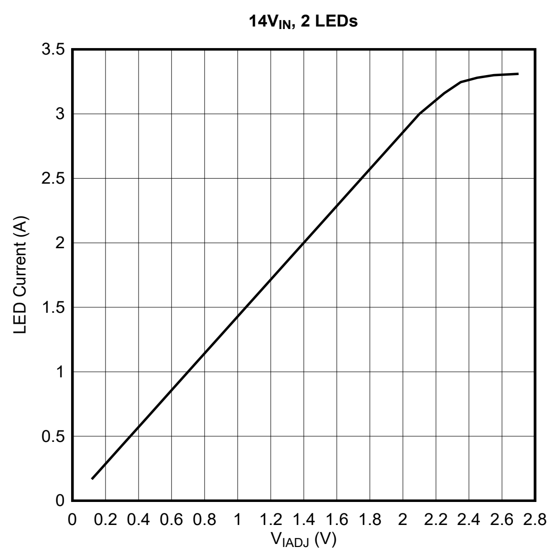


Figure 5-2. Output Current vs IADJ Voltage 14-V Input, 2 LEDs

5.3 PWM Dimming

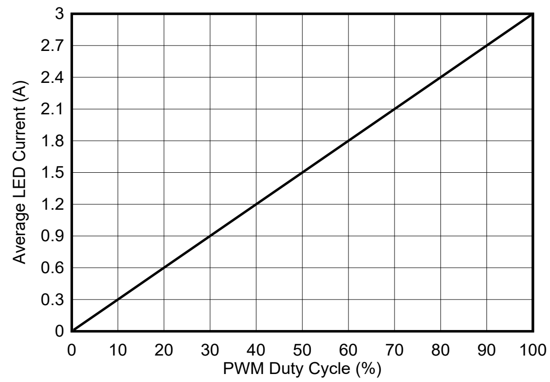


Figure 5-3. Output Current vs PWM Duty Cycle (250 Hz) 14-V Input, 2 LEDs

5.4 PWM Dimming Waveforms

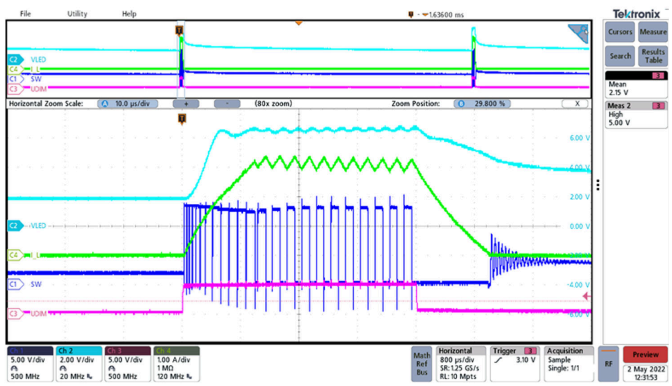


Figure 5-4. 1% Duty Cycle 250-Hz PWM, Input Voltage = 14 V, 2 LEDs

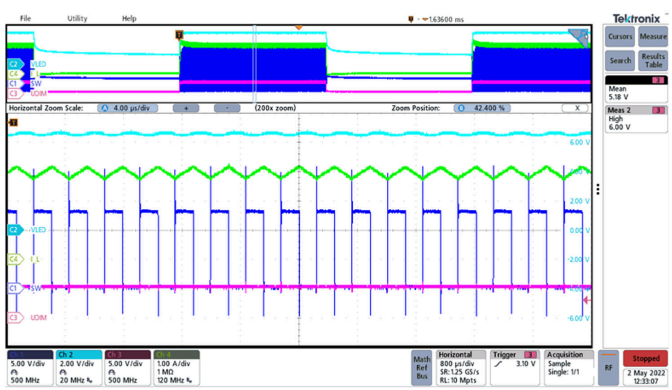


Figure 5-5. 50% Duty Cycle, 250-Hz PWM, Input Voltage = 14 V, 2 LEDs

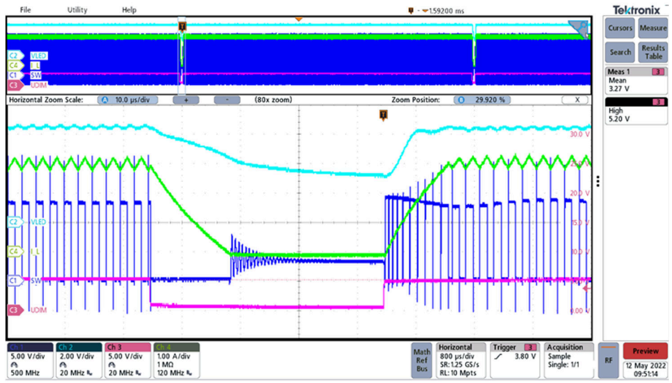


Figure 5-6. 99% Duty Cycle, 250-Hz PWM, Input Voltage = 14 V, 2 LEDs

6 Schematic

Figure 6-1 and Figure 6-2 illustrate the EVM schematic.

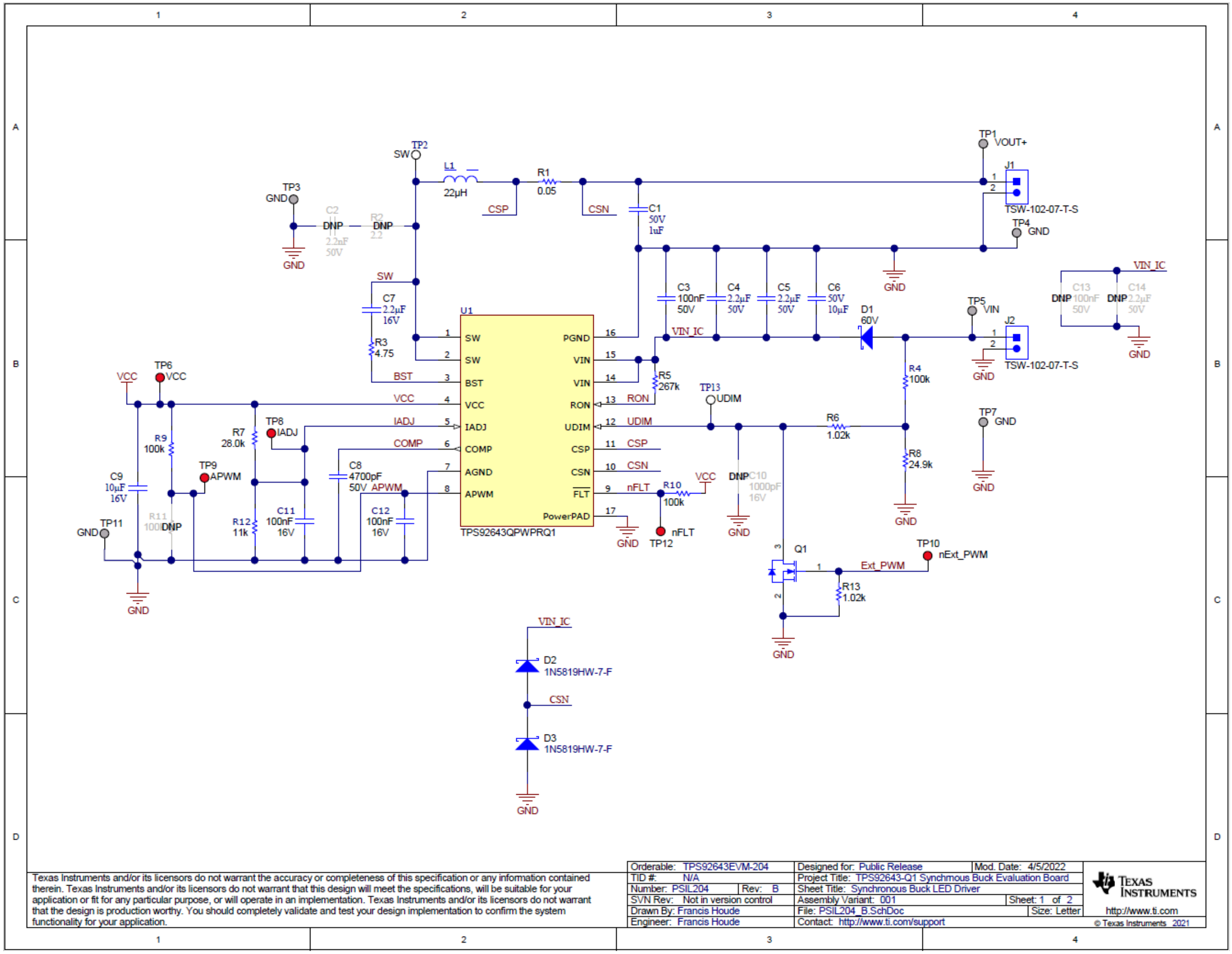


Figure 6-1. TPS92643EVM-204 Schematic Page 1

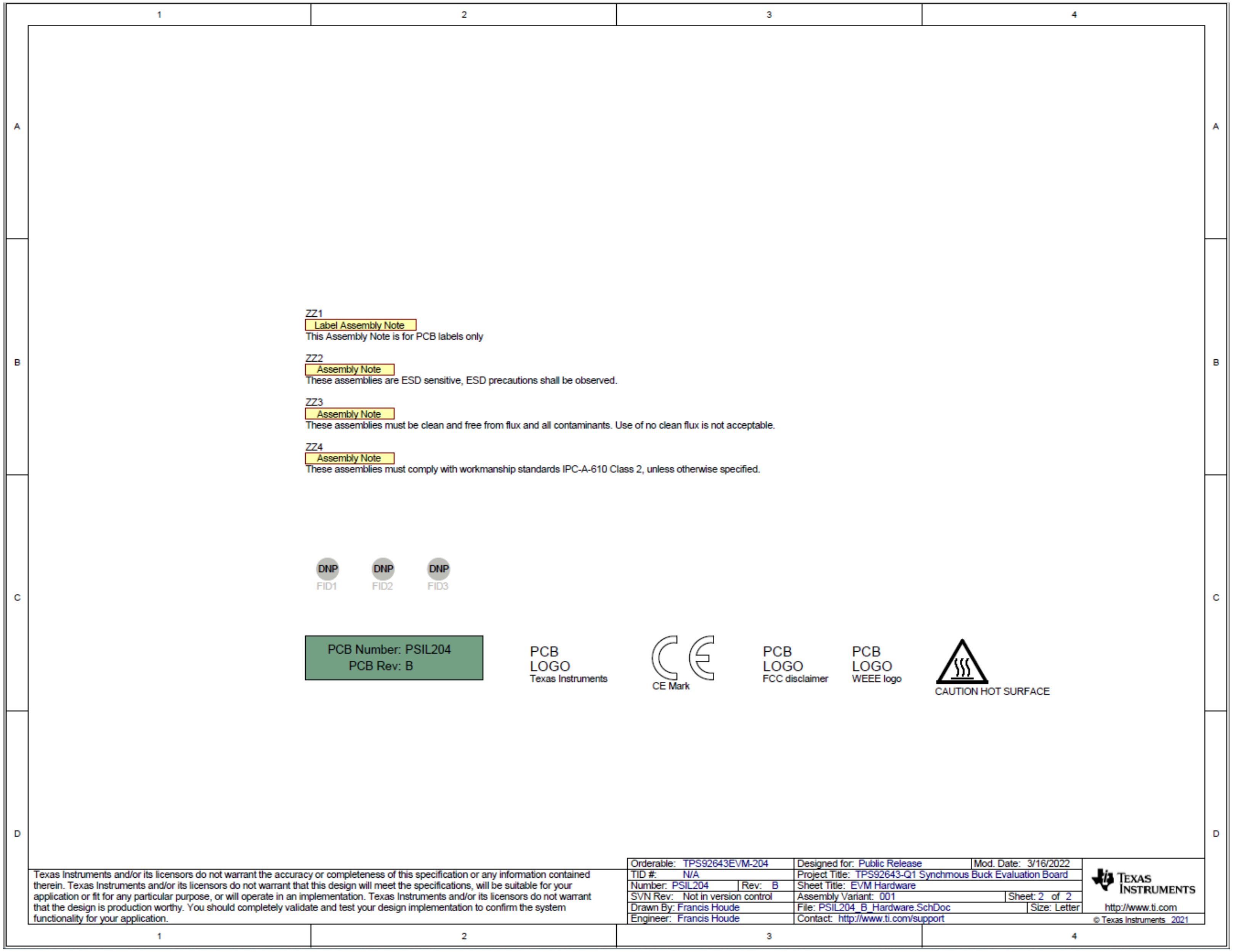


Figure 6-2. TPS92643EVM-204 Schematic Page 2

7 TPS92643EVM-204 PCB Layout

Figure 7-1, Figure 7-2, Figure 7-3, and Figure 7-4 show the design of the TPS92643EVM-204 printed circuit board.

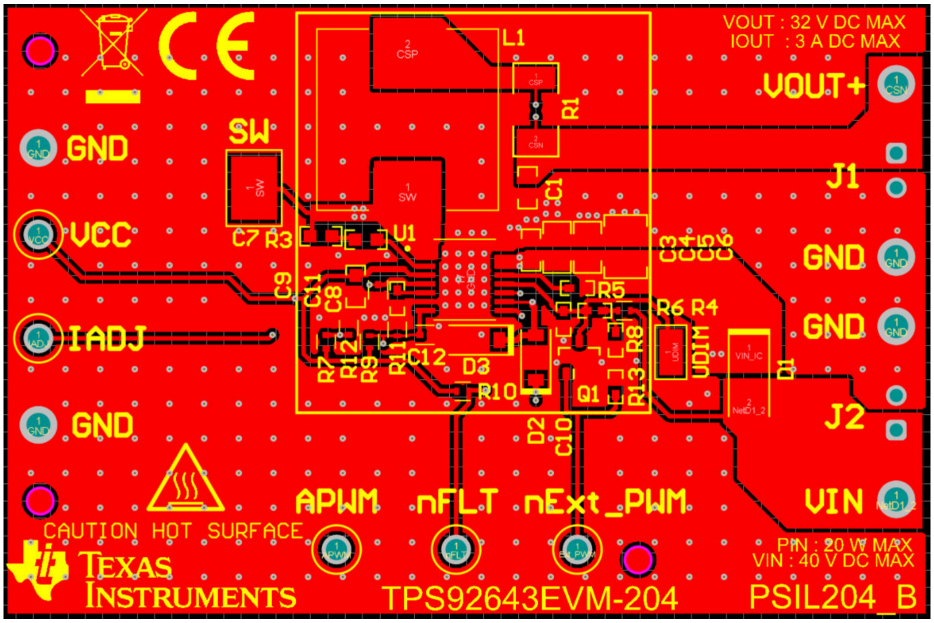


Figure 7-1. Top Layer and Top Overlay (Top View)

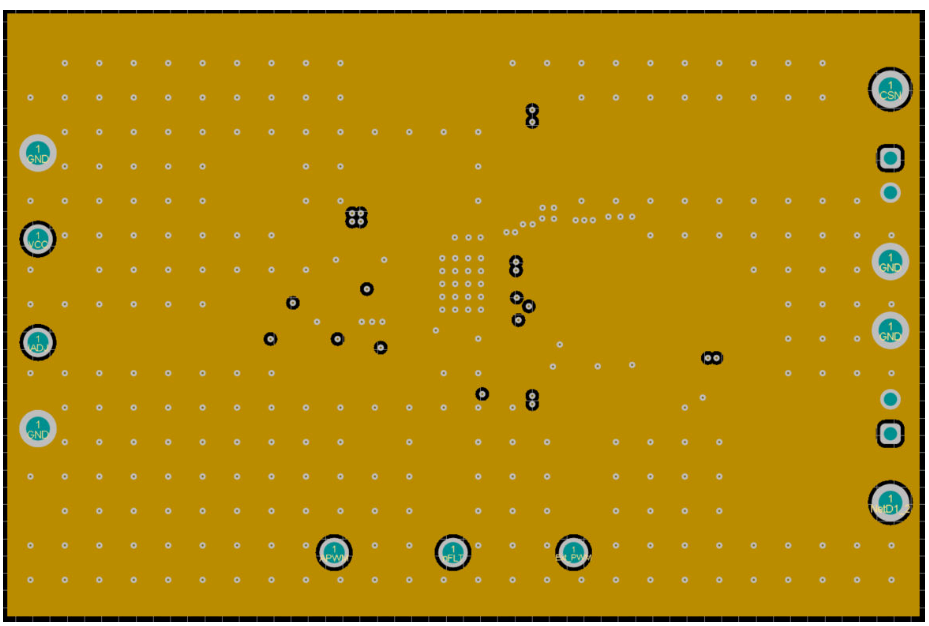


Figure 7-2. Signal Layer 1

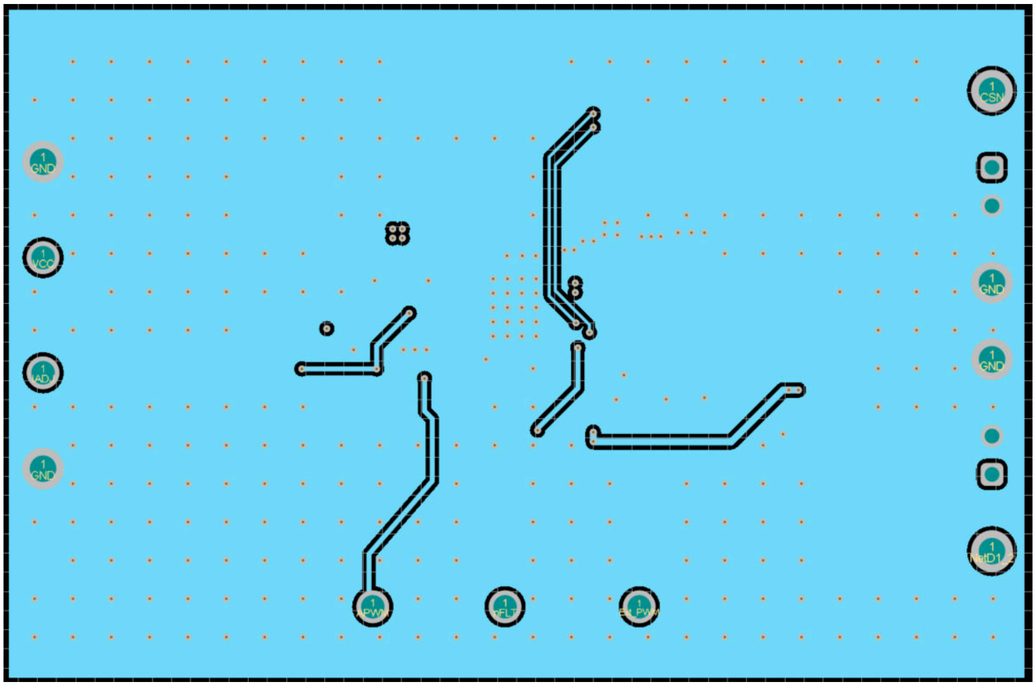


Figure 7-3. Signal Layer 2

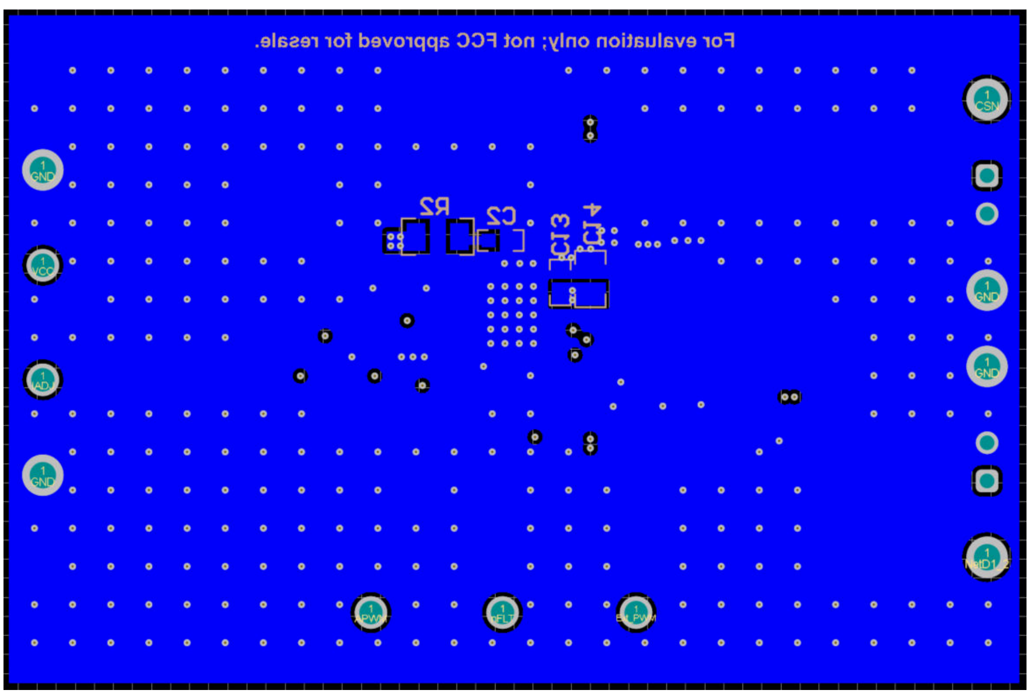


Figure 7-4. Bottom Layer and Bottom Overlay (Bottom View)

8 Bill of Materials

Table 8-1 contains the TPS92643EVM-204 components list according to the schematic shown in Figure 6-1.

Table 8-1. TPS92643EVM-204 Bill of Materials

Reference Designator	QTY	Value	Description	Size	Part Number	MFR
C1	1	1.0 µF	CAP, CERM, 1 uF, 50 V, +/- 10%, X5R, 0603	0603	C1608X5R1H105K080AB	TDK
C3	1	0.1 µF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R1H104K080AA	TDK
C4, C5	2	2.2 µF	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0805	0805	CGA4J3X7R1H225K125AB	TDK
C6	1	10.0 µF	CAP, CERM, 10 µF, 50 V,+/- 10%, X7R, 1210	1210	CL32B106KBJNNWE	Samsung Electro-Mechanics
C7	1	2.2 µF	CAP, CERM, 2.2 µF, 16 V,+/- 10%, X7R, 0603	0603	CC0603KRX7R7BB225	Yageo America
C8	1	4700 pF	CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	0402	GCM155R71H472KA37D	MuRata
C9	1	10.0 µF	CAP, CERM, 10 µF, 16 V,+/- 20%, X6S, AEC-Q200 Grade 2, 0603	0603	GRT188C81C106ME13D	MuRata
C10	0	1000 pF	CAP, CERM, 1000 pF, 16 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0402	0402	AC0402KRX7R7BB102	Yageo
C11, C12	2	100 nF	0.1µF ±10% 16V Ceramic Capacitor X7R 0402 (1005 Metric)	0402	ATC530L104KT16T	American Technical Ceramics
D1	1	60 V	Diode, Schottky, 60 V, 3 A, AEC-Q101, SMA	SMA	B360AM-13-F	Diodes Inc.
D2, D3	2	40V	Diode, Schottky, 40 V, 1 A, SOD-123	SOD-123	1N5819HW-7-F	Diodes Inc.
J1, J2	2		Header, 2.54 mm, 2x1, Tin, TH	Header, 2.54 mm, 2x1, TH	TSW-102-07-T-S	Samtec
L1	1	22.0 µH	22 µH Shielded Wirewound Inductor 6 A 24.7mOhm Nonstandard	SMD_IND_12MM8_12MM8	7443551221	Wurth Electronics
Q1	1	30 V	MOSFET, N-CH, 30 V, 0.85 A, SOT-23	SOT-23	BSH103,215	Nexperia
R1	1	0.050	RES, 0.05, 1%, 1 W, 2010	2010	CSRN2010FK50L0	Stackpole Electronics Inc
R2	1	4.75	RES, 4.75, 1%, 0.1 W, 0603	0603	RC0603FR-074R75L	Yageo
R4, R9, R10	3	100.0 k	100 kOhms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Thick Film	0402	CRCW0402100KFKEDC	Vishay-Dale
R5	1	267 k	RES, 267 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K02FKED	Vishay-Dale
R6, R13	2	1.02 k	RES, 1.02 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K02FKED	Vishay-Dale
R7	1	28 k	28 kOhms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	0402	CRCW040228K0FKED	Vishay-Dale
R8	1	24.9 k	RES, 24.9 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040224K9FKED	Vishay-Dale
R12	1	11 k	11 kOhms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	0402	RMCF0402FT11K0	Stackpole Electronics Inc
TP1, TP3, TP4, TP5, TP7, TP11	6		Terminal, Turret, TH, Double	Keystone1593-2	1593-2	Keystone

Table 8-1. TPS92643EVM-204 Bill of Materials (continued)

Reference Designator	QTY	Value	Description	Size	Part Number	MFR
TP2	1		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone
TP6, TP8, TP9, TP10, TP12	5		Test Point, Multipurpose, Red, TH	Multipurpose Testpoint	5010	Keystone
TP13	1		Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone
TP21, TP22, TP24	3		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone
U1	1		3-A Synchronous Buck LED Driver	HTSSOP16	TPS92643QPWPRQ1	Texas Instruments
R2	0	2.2	RES, 2.2, 5%, 0.5 W, 1206	1206	CRM1206-JW-2R2ELF	Bourns
R11	0	100 k	100 kOhms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Thick Film	0402	CRCW0402100KFKEDC	Vishay-Dale
C2	0	2200 pF	CAP, CERM, 2200 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603C222K5RAC	Kemet
C14	0	2.2 uF	CAP, CERM, 2.2 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0805	0805	CGA4J3X7R1H225K125AB	TDK
C13	0	0.1 uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E2X7R1H104K080AA	TDK

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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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２４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。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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