TPS922051/0 65V 2A/1A Buck LED Driver Evaluation Module with PWM/Analog Dimming

TEXAS INSTRUMENTS

Description

The TPS922051/0 evaluation module (EVM) is a two-layer PCB assembly with multiple variants to help the user evaluate the main features and performance of the TPS922051/0 device family. The TPS922051/0 is a 2A / 1A non-synchronous Buck LED driver with 4.5V to 65V wide input range with PWM / analog dimming function. By integrating the low-side NMOS, the device is capable of driving LEDs with high power density and high efficiency. This document includes setup guidance, schematics, printed-circuit board (PCB) layouts, and bill of materials (BOM) for the whole family of TPS922051/0 EVMs, including TPS922051D1DSGREVM, TPS922051D2DSGREVM, TPS922050D1DSGREVM, TPS922050D2DSGREVM, TPS922051D1DGNREVM, TPS922051D2DGNREVM, TPS922050D1DGNREVM, TPS922050D2DGNREVM, TPS922050D1DRLREVM and TPS922050D2DRLREVM.

Features

- LED common anode connection
- Integrated 300mΩ MOSFET

  - Typical current limit (1.6A / 3.2A)
  - Switching frequency (400kHz / 1MHz)
- Advanced dimming options:

  - D1 for PWM dimming
  - D2 for Analog dimming
- Full protection features:

  - LED open and short protection
  - Switching FET open and short protection
  - External component failure protection
  - Cycle-by-cycle current limit
  - Thermal shutdown
- Package: WSON-8, HVSSOP-8, SOT583

Applications

- Constant illumination:

  - Indoor and outdoor lighting
  - Appliance lighting
  - Cold/warm WLED lighting
  - Emergency and signage lighting
  - Security floodlight
  - LED bulb and lamp
  - LCD backlight
- Instant illumination

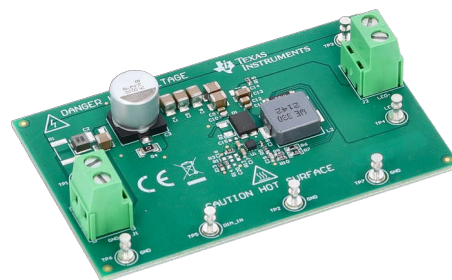 - Machine vision and camera flash
  - Fire alarm and strobe

Figure 1-1. TPS922051D1DSGREVM

1 Evaluation Module Overview

1.1 Introduction

The TPS922051/0 evaluation module (EVM) is designed for evaluating the device family of TPS922051/0 LED driver.
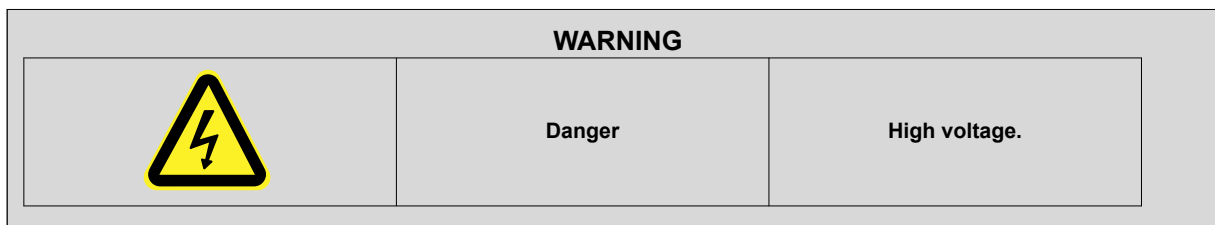
Table 1-1 lists the available EVMs in the TPS922051/0 EVM family, the corresponding chip mounted on the PCB and its features. Multiple EVM variants may share one PCB through BOM variation. For example, TPS922050D1DRLREVM and TPS922050D2DRLREVM share the same PCB (LED036) but are populated with different components. LED034 is for WSON package. LED035 is for HVSSOP package. LED036 is for SOT583 package.

Table 1-1. Summary of Available EVMs

EVM PCB Name	EVM Part Number	Chip Part Number	Package	Typical Current Limit	Switching Frequency	Dimming Method
LED034	TPS922051D1DSGREVM	TPS922051D1DSGR	WSON (8)	3.2A	400kHz	PWM
	TPS922051D2DSGREVM	TPS922051D2DSGR	WSON (8)	3.2A	400kHz	Analog
	TPS922050D1DSGREVM	TPS922050D1DSGR	WSON (8)	1.6A	1MHz	PWM
	TPS922050D2DSGREVM	TPS922050D2DSGR	WSON (8)	1.6A	1MHz	Analog
LED035	TPS922051D1DGNREVM	TPS922051D1DGNR	HVSSOP (8)	3.2A	400kHz	PWM
	TPS922051D2DGNREVM	TPS922051D2DGNR	HVSSOP (8)	3.2A	400kHz	Analog
	TPS922050D1DGNREVM	TPS922050D1DGNR	HVSSOP (8)	1.6A	1MHz	PWM
	TPS922050D2DGNREVM	TPS922050D2DGNR	HVSSOP (8)	1.6A	1MHz	Analog
LED036	TPS922050D1DRLREVM	TPS922050D1DRLR	SOT583 (8)	1.6A	400kHz	PWM
	TPS922050D2DRLREVM	TPS922050D2DRLR	SOT583 (8)	1.6A	400kHz	Analog

CAUTION		
⚠️	**Caution**	**Read the user's guide before use.**

CAUTION		
⚠️	**Caution**	**Hot surface. Contact can cause burns. Do not touch!**

WARNING		
	Danger	High voltage.

1.2 Kit Contents

• TPS922051/0 EVM × 1

Please refer to Table 1-1 for the available EVMs in the TPS922051/0 EVM family.

1.3 Specification

The TPS922051/0 evaluation module (EVM) is built on the fundamental application circuit of TPS922051/0. Additional EMI filtering circuitry is implemented on the EVM, including RC snubber (R2, C15, not populated) and power line LC filter (L1, C1). Additional DIM pin conditioning circuitry is implemented to provide the user with more application possibilities like controlling the D2 version with PWM signal through an RC filter at the DIM pin.

Table 1-2 lists the recommended operating conditions for TPS922051/0 EVM.

Table 1-3 lists the electrical performance specifications for TPS922051/0 EVM.

Table 1-2. Recommended Operating Conditions for TPS922051/0 EVM

Parameter	Conditions	MIN	TYP	MAX	Units
Input Voltage, V_{IN}		4.5		60	V
LED Load Voltage		0		V_{IN}	V
DIM Voltage	All D1 version	0		5	V
	All D2 version	0		2	V
IC Operating Junction Temperature		-40		125	°C

Table 1-3. Electrical Performance Specifications for TPS922051/0 EVM

Parameter	Conditions	MIN	TYP	MAX	Units
Output Current	All TPS922051 EVM (For D1 version, DIM = 3.3VDC. For D2 version, DIM = 2VDC)		2		A
	All TPS922050 EVM (For D1 version, DIM = 3.3VDC. For D2 version, DIM = 2VDC)		1		A
Input Current	All TPS922051 EVM (For D1 version, DIM = 3.3VDC. For D2 version, DIM = 2VDC) in normal working conditions			3.6	A
	All TPS922050 EVM (For D1 version, DIM = 3.3VDC. For D2 version, DIM = 2VDC) in normal working conditions			1.8	A

1.4 Device Information

The TPS922051/0 is a 2A / 1A non-synchronous Buck LED driver with 4.5V to 65V wide input range and PWM / analog dimming function. By integrating the low-side NMOS, the device is capable of driving LEDs with high

power density and high efficiency. The device also supports common anode connection and single layer PCB design. The switching frequency is set at 400kHz or 1MHz.

The D1 version supports PWM dimming by configuring through the DIM input pins by means of simple high and low signals. The D2 version supports analog dimming by configuring through the DIM input pins by means of analog voltage signals. The device adopts an adaptive off-time current mode control along with smart and accurate sampling to enable fast PWM dimming and achieve high dimming ratio.

The TPS922051/0 also provides multiple systematic protections, including LED open and short, switching FET open and short, sense resistor open and short, and thermal shutdown.

1.5 General TI High Voltage Evaluation User Safety Guidelines

⚠️ **WARNING**

Always follow TI's set-up and application instructions, including use of all interface components within the recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center http://support/ti./com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions can result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you must immediately stop from further use of the HV EVM.

- **Work Area Safety:**
  - Maintain a clean and orderly work area .
  - Qualified observers must be present anytime circuits are energized.
  - Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
  - All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50 V_{RMS}/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
  - Use a stable and non-conductive work surface.
  - Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
- **Electrical Safety:**

  As a precautionary measure, a good engineering practice is to assume that the entire EVM can have fully accessible and active high voltages.

  - De-energize the TI HV EVM and all the inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
  - With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
  - When EVM readiness is complete, energize the EVM as intended.

> **WARNING**
> **WARNING: While the EVM is energized, never touch the EVM or the electrical circuits as the EVM or electrical circuits can be at high voltages capable of causing electrical shock hazard.**

- **Personal Safety:**
  - Wear personal protective equipment, for example, latex gloves and/or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.
- **Limitation for Safe Use:**
  - EVMs are not to be used as all or part of a production unit.

Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training, and is designed to operate from an AC power supply or a high-voltage DC supply. Please read this user guide and the safety-related documents that come with the EVM package before operating this EVM.

CAUTION

⚠️

Do not leave the EVM powered when unattended.

WARNING

⚠️

High Voltage! Electric shock is possible when connecting board to live wire. Board must be handled with care by a professional.

For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

---

2 Hardware

2.1 Equipment Requirements

To perform the test on TPS923051/0 EVM, below equipments are required:

- LED load with cables

  - It should be able to carry 2A continuous current for TPS922051 EVM.
  - It should be able to carry 1A continuous current for TPS922050 EVM.
- Function generator with cables

  - It should be set to PWM mode for D1 version EVM.
  - It should be set to DC mode for D2 version EVM.
- Isolated bench power supply with cables

External Power Supply or Power Accessory Requirements:

- Nom Output Voltage: 4.5 - 60 VDC
- Max Output Current: 3600 mA
- Efficiency Level V

NOTE: TI recommends using an external power supply or power accessory which complies with applicable regional safety standards such as (by example) UL, CSA, VDE, CCC, PSE, etc.

2.2 Setup

The EVM can be set up in the below way.

Connect the output of the input power supply to the J1 terminal block. Connect the LED load to the J2 terminal block. Pay attention to the polarity of the LED load. Connect the output of the function generator to the TP5 (positive) and TP2 (negative). As an example, Figure 2-1 shows the connection diagram of TPS922051D1DSGREVM. For other EVMs for WSON package and HVSSOP package, the connection should be done in the same way. For EVMs for SOT583 package, the layout is mirrored to the EVMs for WSON package and HVSSOP package. As an example, Figure 2-2 shows the connection diagram of TPS922050D1DRLREVM. For TPS922050D2DRLREVM, the connection should be done in the same way.
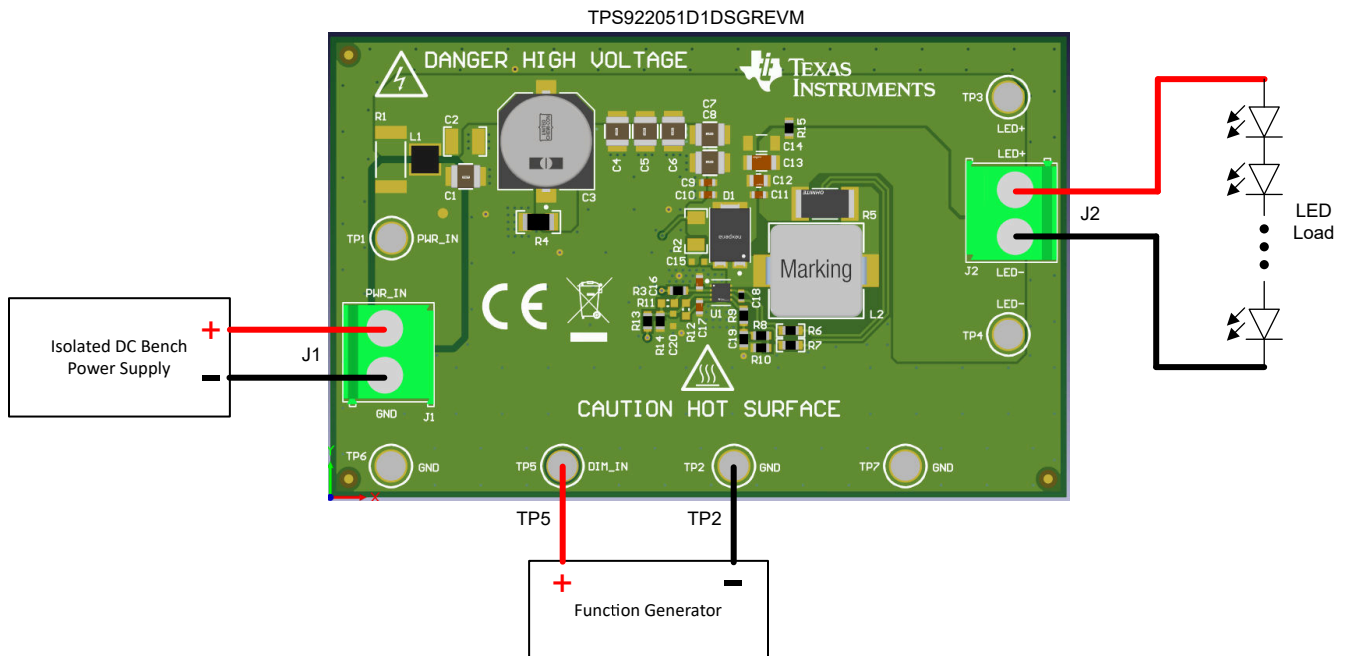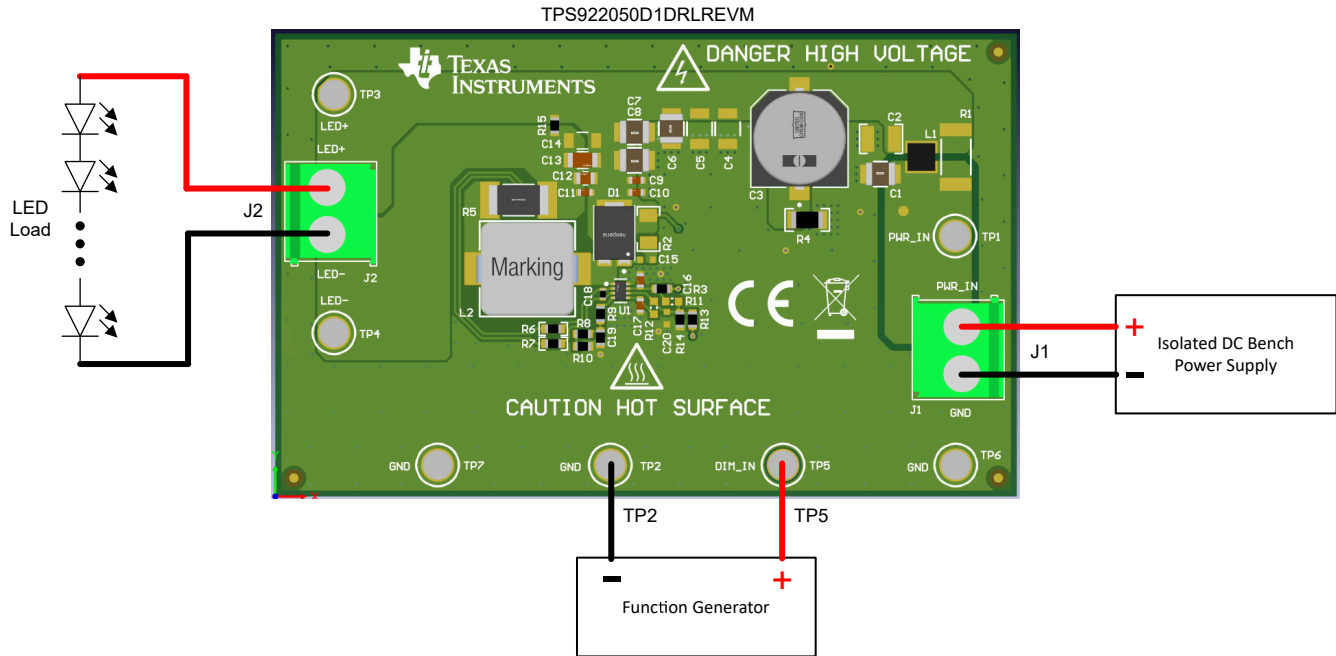

Figure 2-1. Connection Diagram of TPS922051D1DSGREVM

TPS922050D1DRLREVM

Figure 2-2. Connection Diagram of TPS922050D1DRLREVM

2.3 Power Connections

Table 2-1 describes the terminal blocks on the EVM for power connections.

Table 2-1. Terminal Blocks for Power Connections

Designator	Input / Output Type	Port Label	Function
J1	Intput	PWR_IN	Positive power input
		GND	Negative power input (GND)
J2	Output	LED+	Connect to the anode of the LED load
		LED-	Connect to the cathode of the LED load

2.4 Test Points

Table 2-2 describes the test points on the EVM.

Table 2-2. Test Points

Designator	Label	Function
TP1	PWR_IN	Positive power input test point
TP2	GND	Test point to apply negative DIM input signal (GND)
TP3	LED+	LED anode test point
TP4	LED-	LED cathode test point
TP5	DIM_IN	Test point to apply positive DIM input signal
TP6	GND	Negative power input test point (GND)
TP7	GND	GND test point

Copyright © 2024 Texas Instruments Incorporated

3 Implementation Results

3.1 Evaluation Setup

Here the evaluation of TPS922051D1DSGREVM is used as an example.

Input voltage is set at 48 V. Load is 8 white LEDs (Part Number: GW PUSTA1.CM-MENE-XX53-1 from OSRAM) in series. The frequency of the input PWM signal (Low level: 0V, High level: 3.3V) at the DIM pin is set to 1kHz. The duty cycle of the input PWM signal is set to 50%.

3.2 Performance Data and Results

Figure 3-1 shows the LED current and SW waveform of TPS922051D1DSGREVM with the setup shown in Section 3.1.

The signals are described below:

- Black: DIM voltage
- Orange: SW voltage
- Blue: LED current
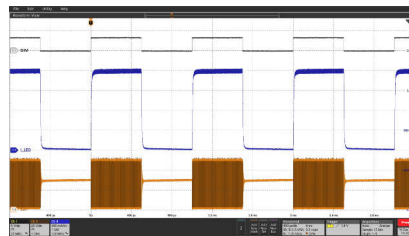
Figure 3-1. LED current and SW waveform of TPS922051D1DSGREVM at DIM$_{PWM}$ = 50%, 1kHz

4 Hardware Design Files

4.1 Schematics

4.1.1 Schematic of LED034 (WSON Package), LED035 (HVSSOP Package)

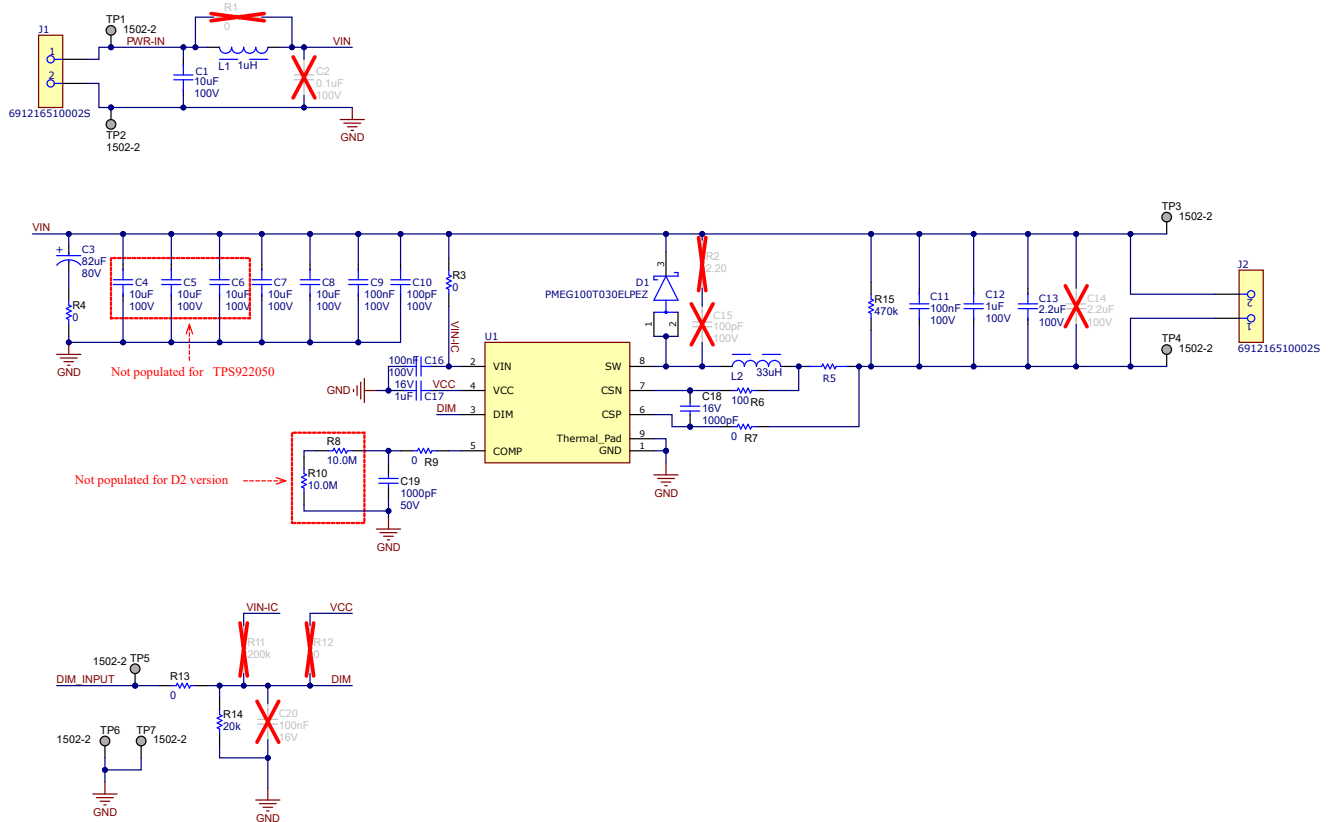The schematic of LED034 (WSON package) and LED035 (HVSSOP package) is shown below.

Figure 4-1. Schematic of LED034, LED035

Copyright © 2024 Texas Instruments Incorporated

4.1.2 Schematic of LED036 (SOT583 Package)

The schematic of LED036 (SOT583 package) is shown below.
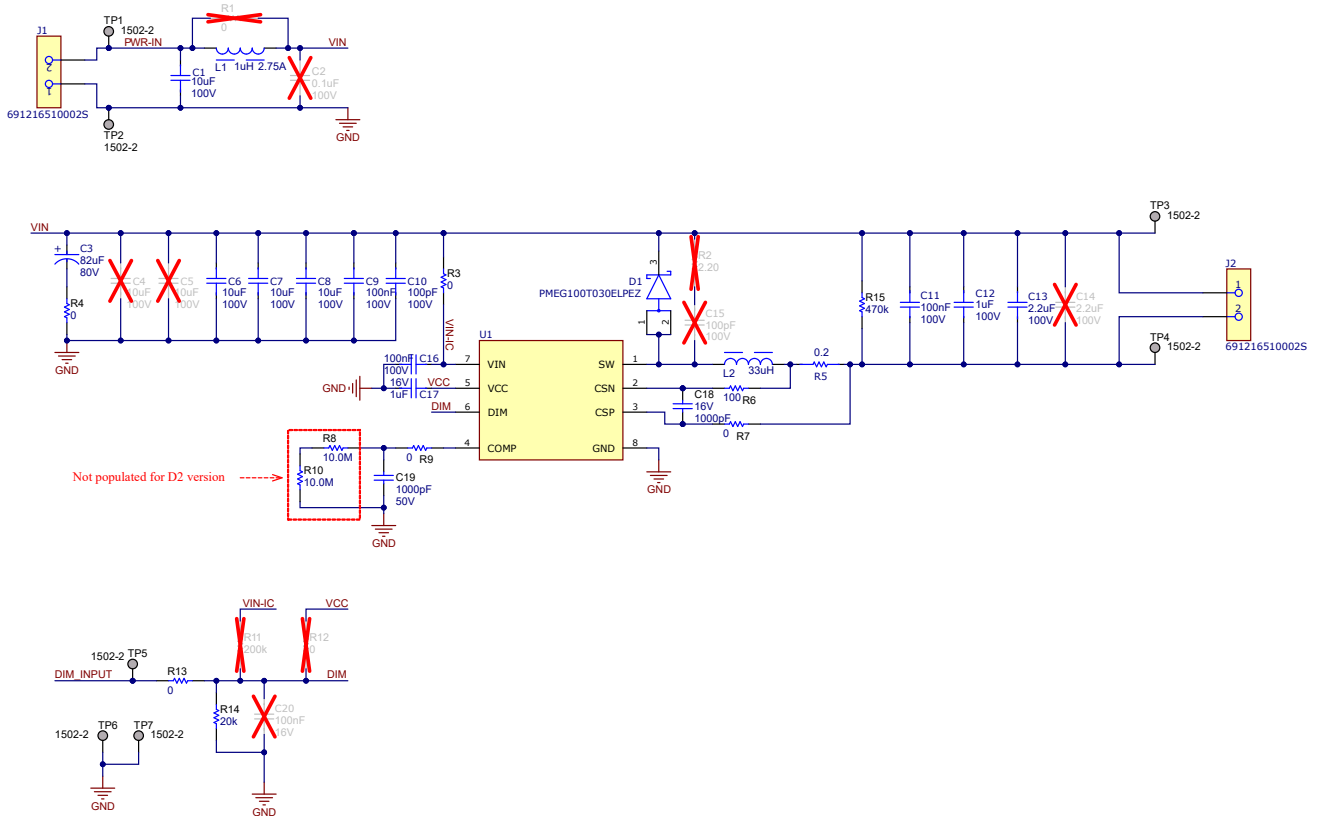
Figure 4-2. Schematic of LED036

4.2 PCB Layouts

4.2.1 PCB Layout of LED034 (WSON Package)
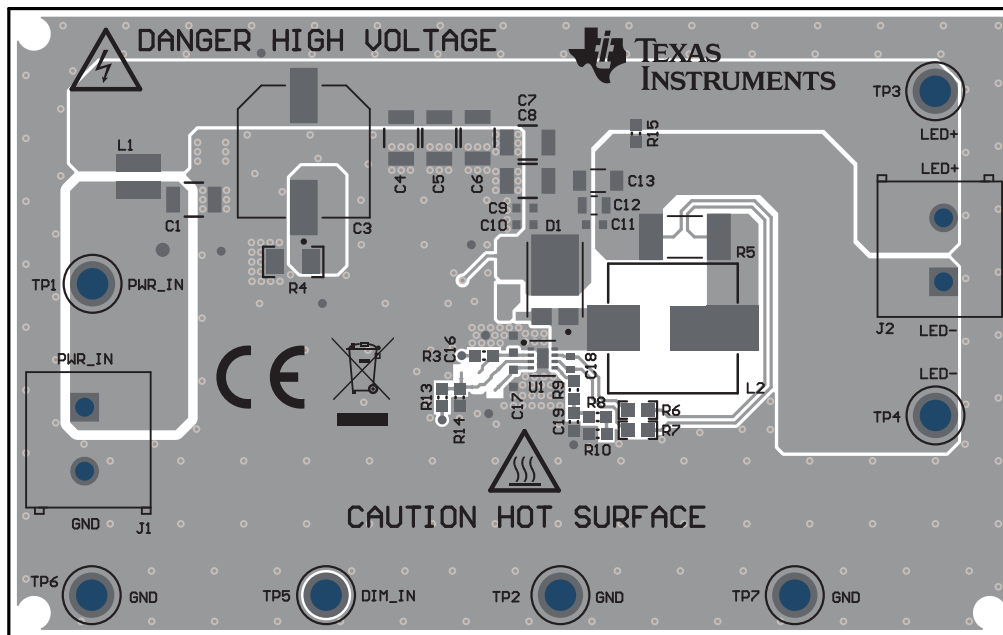
The PCB layout of LED034 (WSON package) is shown below.
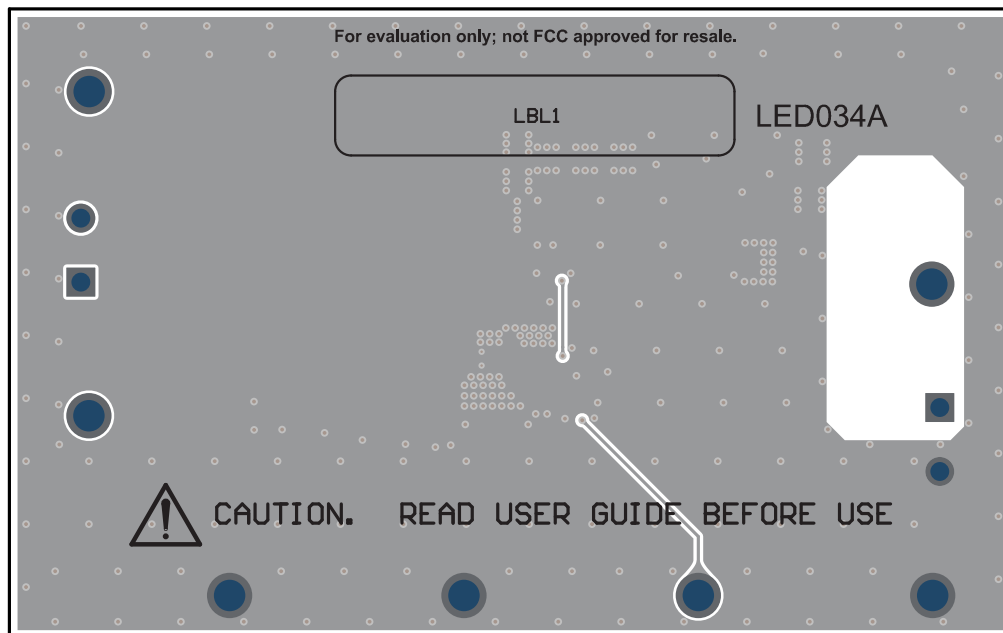

Figure 4-3. LED034 Top Layer

Figure 4-4. LED034 Bottom Layer

4.2.2 PCB Layout of LED035 (HVSSOP Package)

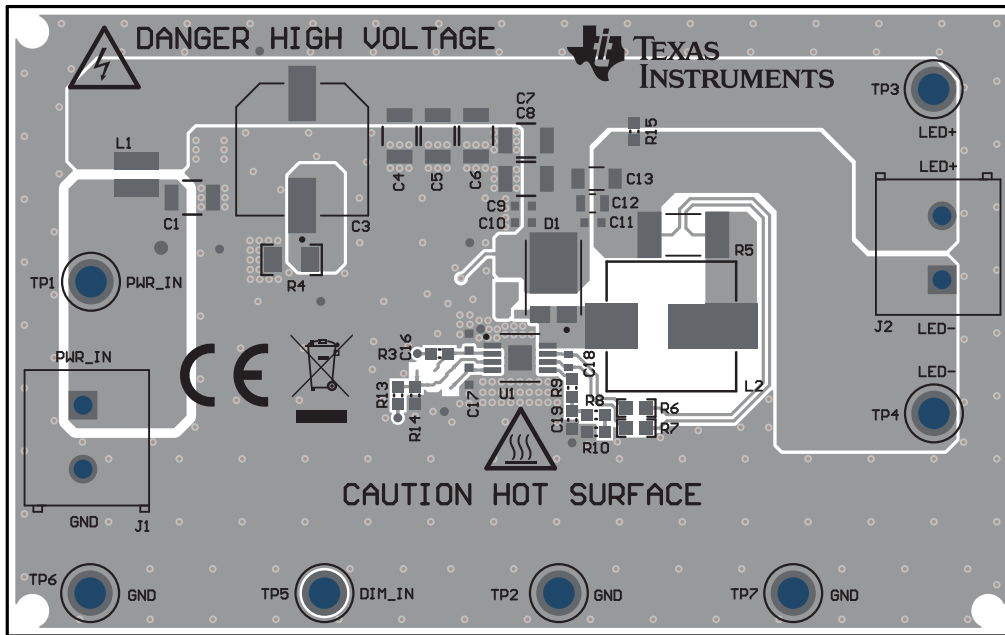The PCB layout of LED035 (HVSSOP package) is shown below.
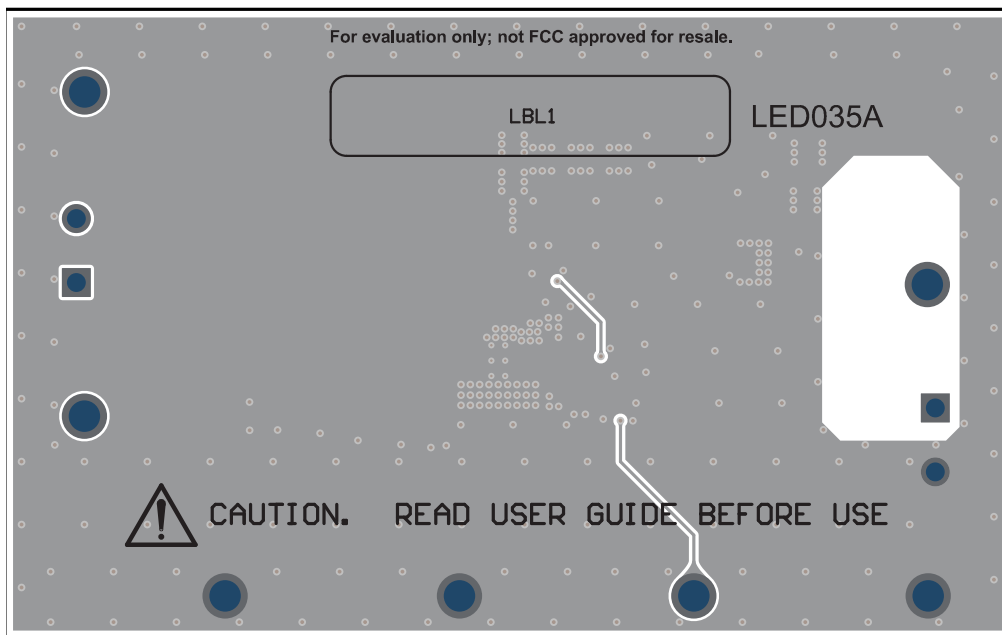
Figure 4-5. LED035 Top Layer

Figure 4-6. LED035 Bottom Layer

4.2.3 PCB Layout of LED036 (SOT583 Package)

The PCB layout of LED036 (SOT583 package) is shown below.
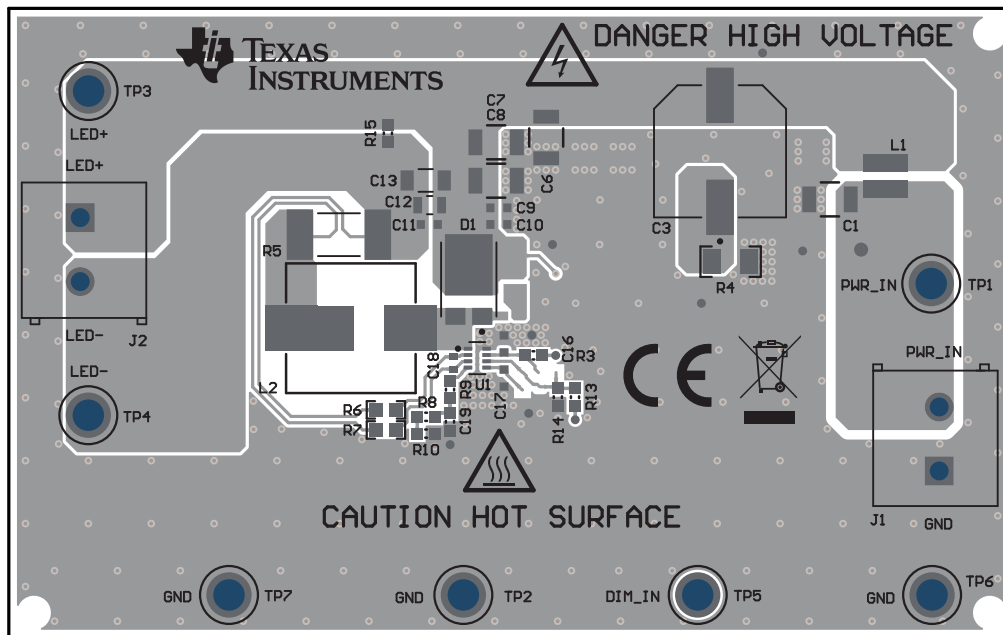
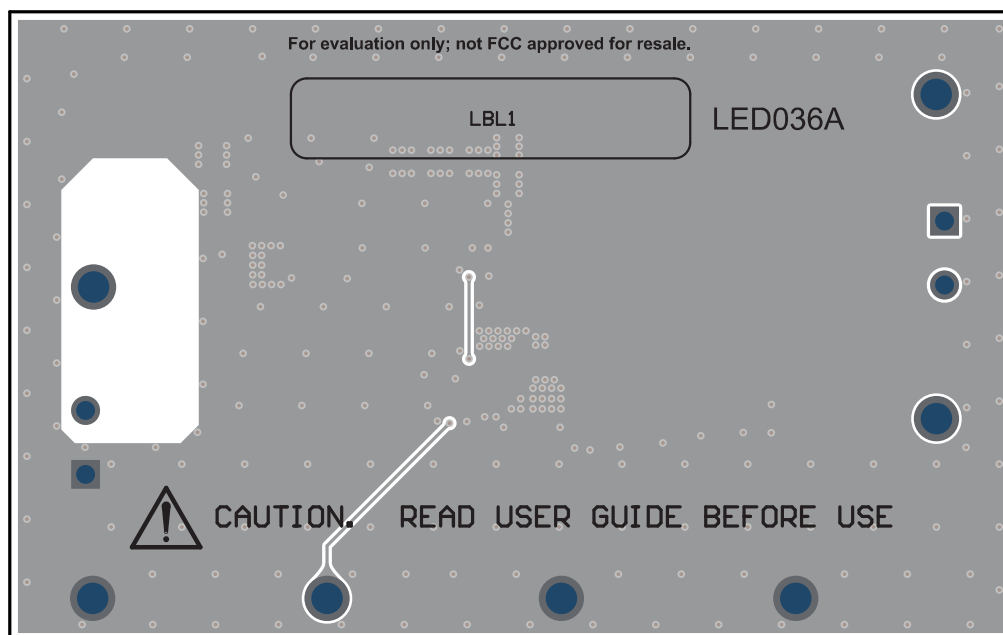**Figure 4-7. LED036 Top Layer**

Figure 4-8. LED036 Bottom Layer

4.3 Bill of Materials (BOM)

The bill of materials (BOM) for LED034 (WSON package), LED035 (HVSSOP package) and LED036 (SOT583 package) is listed in Table 4-1 and Table 4-2. Table 4-1 lists the parts common to all TPS922051/0 EVM variants. Table 4-2 lists the parts exclusive to different TPS922051/0 EVM variants. If the part shows 0 in Qty., it means that the part is not populated on the EVM.

Table 4-1. Common Bill of Materials (BOM) for All TPS922051/0 EVM Variants

Designator	Qty.	Description	Part Number	Manufacturer
C1, C7, C8	3	10µF ±10% 100V Ceramic Capacitor X7S 1210 (3225 Metric)	GRM32EC72A106KE05L	Murata
C3	1	82 µF 80 V Aluminum Electrolytic Capacitors Radial, Can - SMD 450mOhm @ 100kHz 2000 Hrs @ 125°C	EMHS800ARA820MJA0G	United Chemi-Con
C9, C11, C16	3	Chip Multilayer Ceramic Capacitors for General Purpose, 0603, 0.10uF, X7R, 15%, 10%, 100V	GRM188R72A104KA35J	Murata
C10	1	Ceramic Capacitor for Automotive 100pF ±5% 100VDC C0G 0603 Paper T/R	GCM1885C2A101JA16J	Murata
C12	1	1µF ±10% 100V Ceramic Capacitor X7S 0805 (2012 Metric)	GRM21BC72A105KE01L	Murata
C13	1	Chip Multilayer Ceramic Capacitors for General Purpose 2.2µF ±10% 100Vdc	GRM31CL8EL225KE07L	Murata
C17	1	1 µF ±10% 16V Ceramic Capacitor X7S 0603 (1608 Metric)	GRM188C71C105KA12D	Murata
C18	1	CAP, CERM, 1000 pF, 16 V, +/- 10%, X7R, 0402	GRM155R71C102KA01D	MuRata
C19	1	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H102JA01D	MuRata
D1	1	Diode 100 V 3A Surface Mount CFP15B	PMEG100T030ELPEZ	Nexperia
J1, J2	2	2 Position Wire to Board Terminal Block Horizontal with Board 0.200" (5.08mm) Through Hole	691216510002S	Wurth Elektronics
L2	1	WE-LHMI SMT Power Inductor, size 1040, 33uH, 3.75A, 112mOhm	74437368330	Wurth Elektronik
LBL1	1	Thermal Transfer Printable Labels, 1.250" W x 0.250" H - 10,000 per roll	THT-13-457-10	Brady
R3, R7, R9, R13	4	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL	Yageo
R4	1	RES, 0, 5%, 0.25 W, 1206	RC1206JR-070RL	Yageo America
R6	1	RES, 100, 1%, 0.1 W, 0603	RC0603FR-07100RL	Yageo
R14	1	RES, 20 k, 5%, 0.1 W, 0603	RC0603JR-0720KL	Yageo
R15	1	RES, 470 k, 1%, 0.1 W, 0603	RC0603FR-07470KL	Yageo

Table 4-1. Common Bill of Materials (BOM) for All TPS922051/0 EVM Variants (continued)

Designator	Qty.	Description	Part Number	Manufacturer
TP1, TP2, TP3, TP4, TP5, TP6, TP7	7	Terminal, Turret, TH, Double	1502-2	Keystone
C2	0	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 1210	GRM32NR72A104KA01L	MuRata
C14	0	Chip Multilayer Ceramic Capacitors for General Purpose 2.2µF ±10% 100Vdc	GRM31CL8EL225KE07L	Murata
C15	0	Ceramic Capacitor for Automotive 100pF ±5% 100VDC C0G 0603 Paper T/R	GCM1885C2A101JA16J	Murata
C20	0	0.1µF ±10% 16V Ceramic Capacitor X7R 0603 (1608 Metric)	GCJ188R71C104KA01D	Murata Electronics North America
FID1, FID2, FID3	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A
R1	0	RES, 0, 0.05%, 2 W, AEC-Q200 Grade 0, 2512	HCJ2512ZT0R00	Stackpole Electronics Inc
R2	0	RES, 2.20, 1%, 0.25 W, 1206	RC1206FR-072R2L	Yageo America
R11	0	RES, 200 k, 1%, 0.1 W, 0603	RC0603FR-07200KL	Yageo
R12	0	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL	Yageo

Table 4-2. Exclusive Bill of Materials (BOM) for Different TPS922051/0 EVM Variants

Designator	Qty.	Description	Part Number	Manufacturer	EVM Variant
U1	1	65V 2A Buck LED Driver with PWM Dimming, WSON	TPS922051D1DSGR	Texas Instruments	TPS922051D1DSGREVM
	1	65V 2A Buck LED Driver with Analog Dimming, WSON	TPS922051D2DSGR	Texas Instruments	TPS922051D2DSGREVM
	1	65V 1A Buck LED Driver with PWM Dimming, WSON	TPS922050D1DSGR	Texas Instruments	TPS922050D1DSGREVM
	1	65V 1A Buck LED Driver with Analog Dimming, WSON	TPS922050D2DSGR	Texas Instruments	TPS922050D2DSGREVM
	1	65V 2A Buck LED Driver with PWM Dimming, HVSSOP	TPS922051D1DGNR	Texas Instruments	TPS922051D1DGNREVM
	1	65V 2A Buck LED Driver with Analog Dimming, HVSSOP	TPS922051D2DGNR	Texas Instruments	TPS922051D2DGNREVM
	1	65V 1A Buck LED Driver with PWM Dimming, HVSSOP	TPS922050D1DGNR	Texas Instruments	TPS922050D1DGNREVM
	1	65V 1A Buck LED Driver with Analog Dimming, HVSSOP	TPS922050D2DGNR	Texas Instruments	TPS922050D2DGNREVM
	1	65V 1A Buck LED Driver with PWM Dimming, SOT583	TPS922050D1DRLR	Texas Instruments	TPS922050D1DRLREVM
	1	65V 1A Buck LED Driver with Analog Dimming, SOT583	TPS922050D2DRLR	Texas Instruments	TPS922050D2DRLREVM
R5	1	100 mOhms ±0.5% 2W Chip Resistor 2512 (6432 Metric) Current Sense Metal Film	PCS2512DR1000ET	Ohmite	All TPS922051 EVM
	1	200 mOhms ±1% 1W Chip Resistor 2512 (6432 Metric) Anti-Sulfur, Automotive AEC-Q200, Current Sense Metal Element	CRG2512-FZ-R200E-1	Bourns	All TPS922050 EVM
C4, C5	2	10µF ±10% 100V Ceramic Capacitor X7S 1210 (3225 Metric)	GRM32EC72A106KE05L	Murata	All TPS922051 EVM
	0	10µF ±10% 100V Ceramic Capacitor X7S 1210 (3225 Metric)	GRM32EC72A106KE05L	Murata	All TPS922050 EVM

Table 4-2. Exclusive Bill of Materials (BOM) for Different TPS922051/0 EVM Variants (continued)

Designator	Qty.	Description	Part Number	Manufacturer	EVM Variant
C6	1	10µF ±10% 100V Ceramic Capacitor X7S 1210 (3225 Metric)	GRM32EC72A106KE05L	Murata	All TPS922051 EVM, TPS922050D1DRLREVM, TPS922050D2DRLREVM
	0	10µF ±10% 100V Ceramic Capacitor X7S 1210 (3225 Metric)	GRM32EC72A106KE05L	Murata	All TPS922050 EVM for WSON and HVSSOP package
R8, R10	2	RES, 10.0 M, 1%, 0.1 W, 0603	RC0603FR-0710ML	Yageo	All D1 version EVM (PWM dimming)
	0	RES, 10.0 M, 1%, 0.1 W, 0603	RC0603FR-0710ML	Yageo	All D2 version EVM (analog dimming)
L1	1	WE-MAPI SMT Power Inductor, size 3020, 1uH, 4A, 32mOhm	74438336010	Wurth Elektronik	All TPS922051 EVM
	1	WE-MAPI SMT Power Inductor, size 3012, 1uH, 2.75A, 50.5mOhm	74438334010	Wurth Elektronik	All TPS922050 EVM

5 Compliance Information

5.1 Compliance and Certifications

- TPS922051D1DSGREVM EU Declaration of Conformity (DoC)

6 Additional Information

6.1 Trademarks

All trademarks are the property of their respective owners.

7 Related Documentation

- [TPS922050/1 65V 1A/2A Buck LED Driver with PWM/Analog Dimming datasheet](#)

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。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.

IMPORTANT NOTICE AND DISCLAIMER