EVM User's Guide: TPS92365x

TPS92365xEVM 65V, 2A/4A Boost/Buck-Boost LED Driver Evaluation Module

Description

This user’s guide describes the TPS92365x evaluation module, including TPS923655DMTREVM, TPS923655DRRREVM and TPS923653DYYREVM. This user’s guide is used as a reference for engineering evaluation. Included in this user’s guide are test setup instructions, characteristics curves and waveforms, a schematic diagram, a printed board (PCB) layout, and a bill of materials (BOM).

Get Started

1. Read and study this user's guide completely before evaluating
2. Order the TPS92365xEVM for evaluation if step 1 met
3. Setup and test the TPS92365xEVM per user's guide instructions

Features

- 4.5V to 65V wide input range
- LED cathode connection for boost/buck-boost mode
- Integrated 150mΩ MOSFET
- Optional switching frequency: 100kHz to 2.2MHz
- Spread spectrum for TPS923653 and TPS923655
- Advanced dimming options:
  - Analog dimming (256:1)
  - Fast PWM dimming (150ns pulse width)
  - Hybrid and flexible dimming (2,000:1 at 20kHz PWM, 10,000:1 at 4kHz PWM, 1,000,000:1 at 120Hz PWM)

Applications

- Constant illumination:
  - Indoor, outdoor, professional lighting
  - Medical, surgical lighting
  - Projector, laser TV, printer, IP camera
- Instant illumination:
  - Machine vision, camera flash
  - Fire alarm, strobe

1 Introduction

The TPS92365x EVM evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92365x non-synchronous boost/buck-boost switching regulator designed for high-current and ultra-deep dimming ratio LED driver applications. The TPS92365x is a 2A/4A non-synchronous boost/buck-boost LED driver and features a wide input voltage range (4.5V to 65V) and four dimming options, including analog dimming, PWM dimming, hybrid dimming and flexible dimming. Each dimming mode can be configured through the PWM/EN and ADIM/HD input pins by means of simple high/low signals. It also provides full protections, including LED open protection and short protection, sense resistor open protection and short protection, configurable thermal foldback and thermal shutdown. The TPS92365x EVM evaluation module (EVM) series include TPS923655DMTREVM, TPS923655DRRREVM and TPS923653DYYREVM.

2 Warnings and Cautions

Observe the following precautions when using the TPS92365xEVM.

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 TPS92365xEVM provides an LED driver based on the TPS92365x boost/buck-boost switching regulator. It is designed to operate with an input voltage in the range of 4.5 V to 65 V. The EVM is set up for a default output current of 2 A and can work in four configurable dimming options. Please refer to TPS92365x datasheet (literature number: SLVSGH1) for more detailed information on configurable dimming options. By applying 0-100% duty cycle PWM signal on ADIM/HD pin or PWM/EN pin, device is able to operate in analog dimming or PWM dimming respectively. For analog dimming, it can provide dimming ratio up to 256:1. For PWM dimming, it can output pulse with width down to 200 ns. The TPS92365x integrates hybrid dimming mode that combines analog dimming and PWM dimming with a fixed transition point (1/8 target current) to maximize dimming performance. To further increase the flexibility of dimming control, flexible dimming mode is also available to independently control LED current value and the on/off behavior. The TPS92365x can provide features like wide voltage range, high current rating and ultra-deep dimming range.

3.1 Typical Applications

This design describes an application of the TPS92365x as an LED driver using the following specifications. For applications with a different input voltage range or different output voltage and current, please refer to the TPS92365x data sheet.

Table 3-1 lists the electrical performance specifications.

Table 3-1. TPS92365xEVM Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	Units
Input voltage range, V_{IN}		4.5		60	V
LED forward voltage	Single white LED		3		V
Output voltage range, V_{OUT}	LED+ to LED–, depends on V_{IN}			60	V
Output current	3.3V, 100% duty, PWM input at ADIM/HD pin (TPS923655DMTREVM, TPS923655DRRREVM)		2		A
	3.3V, 100% duty, PWM input at ADIM/HD pin (TPS923653DYYREVM)		2		A
Output current ripple	V_{IN} = 24V, 15 white LEDs, 2A output current		100		mApp
Analog dimming range	3.3V PWM at ADIM/HD pin	1		100	%
Analog dimming frequency		0.1		100	kHz
PWM dimming range	3.3V PWM at PWM/EN pin	1		100	%
PWM dimming frequency		0.1		50	kHz
Switching frequency			400		kHz
Efficiency	V_{IN} = 24V, 15 white LEDs, 2A output current		95		%

4 Test Setup

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92365xEVM.

4.1 Connector Description

Table 4-1. EVM Connectors and Test Points

Reference Designator	Function
J1	Connect to Power Input
J2	Connect to the anode and cathode of the LED load in Boost connection
J5	Connect to the anode and cathode of the LED load in Buck-Boost connection
J3	ADIM/HD optional connection to V_{LDO} or GND
J4	PWM/EN optional connection to V_{LDO} or GND
TP1, TP3	Positive and Negative power input test point
TP4	LED load anode test point in Boost and Buck-Boost connection
TP13	LED load cathode test point in Boost connection
TP2	LED load cathode test point in Buck-Boost connection
TP10	ADIM/HD signal input
TP11	PWM/EN signal input
TP12	FAULT test point
TP5, TP6	AGND test point
TP7, TP8, TP9	PGND test point

4.2 Input/Output Connection

A power supply capable of supplying 4A must be connected to J1 through a pair of 20-AWG wires. In Boost connection, the LED load must be connected to TP4, TP13 or J2 through a pair of 20-AWG wires. The positive terminal of the LED load should be connected to the TP4 or J2 terminal beside TP4, and the negative terminal of the LED load should be connected to the TP13 or J2 terminal beside TP13. In Buck-Boost connection, the LED load must be connected to TP4, TP2 or J5 through a pair of 20-AWG wires. The positive terminal of the LED load should be connected to the TP4 or J5 terminal beside TP4, and the negative terminal of the LED load should be connected to the TP2 or J5 terminal beside TP2. Wires should be twisted and kept as short as possible to minimize voltage drop, inductance, and EMI transmission.

TP10 and TP11 are the input terminals for control signals of different dimming modes. The configuration to one of the four dimming modes are shown in Table 4-2. For high signal, the DC voltage level should be higher than 1.2V, typically 3.3V. For PWM signal on PWM/EN pin or ADIM/HD pin, it should be a square wave with a low level of GND and a high level voltage higher than 1.2V, typically 3.3V. The dimming frequency should be in the range of 0.1kHz and 50kHz for PWM signal at PWM/EN pin. While for PWM signal on ADIM/HD pin, dimming frequency should be within 0.1kHz and 100kHz.

Table 4-2. Dimming Mode Configuration

Dimming Mode	PWM/EN Pin	ADIM/HD Pin
PWM dimming	PWM signal	High
Analog dimming	High	PWM signal
Hybrid dimming	PWM signal	Low
Flexible dimming	PWM signal	PWM signal

5 Typical Characteristics Curves and Waveforms

This section describes the typical characteristics of the TPS92365xEVM with curves and waveforms from the test. The ambient temperature for test is 25°C, unless otherwise noted. Several LEDs may be paralleled in the test to increase the overall current capability of the load.

5.1 Efficiency

Figure 5-1 shows the efficiency versus input duty cycle in analog dimming mode. The full-scale LED current I_{FS} is set at 2A. The frequency of the input PWM signal at the ADIM/HD pin is 20kHz. Input voltage V_{IN} is 24V. The load is 16 white LEDs in series.

Figure 5-2 shows the efficiency versus input duty cycle in PWM dimming mode. The full-scale LED current I_{FS} is set at 2A. The frequency of the input PWM signal at the PWM/EN pin is 20kHz. Input voltage V_{IN} is 24V. The load is 16 white LEDs in series.

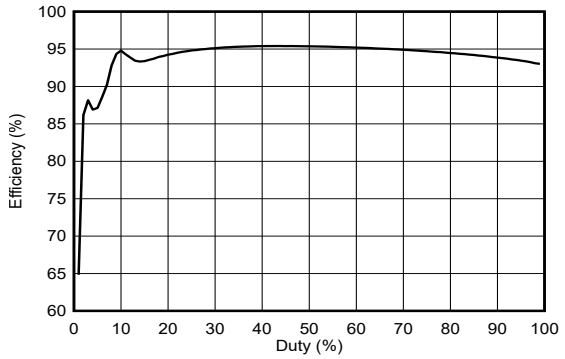

Figure 5-1. Efficiency vs. Input Duty Cycle in Analog Dimming Mode

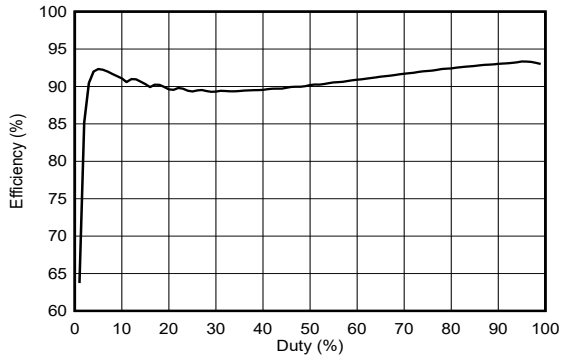

Figure 5-2. Efficiency vs. Input Duty Cycle in PWM Dimming Mode

5.2 Line Regulation

Figure 5-3 shows the output current deviation ratio vs. input voltage. Input voltage is 24V. 15 white LEDs in series are used as load. The LED current is set at 2A and 0.5A, respectively.

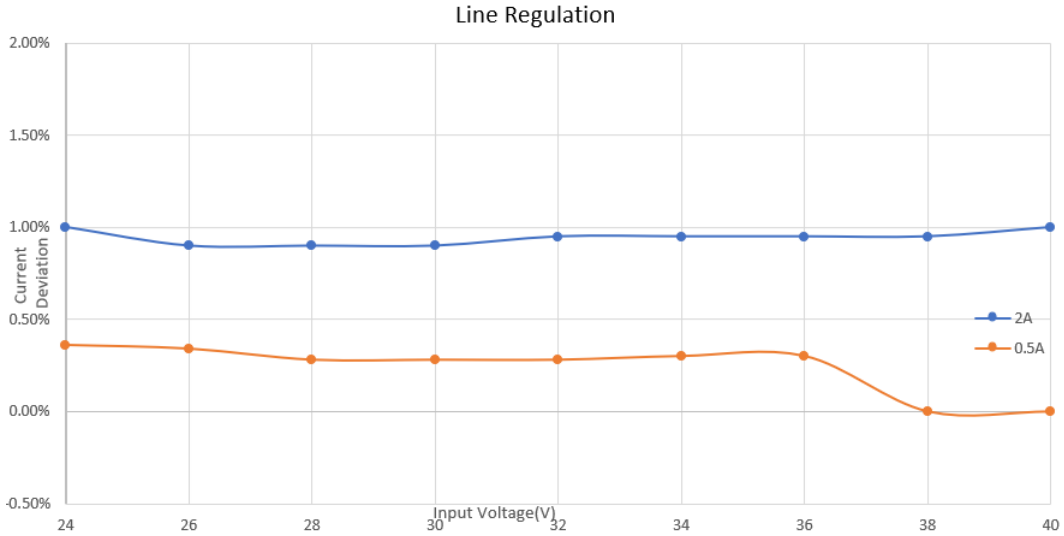

Figure 5-3. LED Current Deviation vs. Input Voltage

5.3 Load Regulation

Figure 5-4 shows the LED current deviation vs. the number of LEDs in series in analog dimming mode. Input voltage V_{IN} is set at 24V. LED current is set at 0.5A and 2A with analog dimming. White LEDs are used as load. The number of LEDs in series is 10, 11, 12, 13, 14, 15, and 16, respectively. The frequency of the input PWM signal at the ADIM/HD pin is 20kHz.

Figure 5-5 shows the LED current deviation vs. the number of LEDs in series in PWM dimming mode. Input voltage V_{IN} is set at 24V. LED current is set at 0.5A and 2A with PWM dimming. White LEDs are used as load. The number of LEDs in series is 10, 11, 12, 13, 14, 15, and 16, respectively. The frequency of the input PWM signal at the PWM/EN pin is 20kHz.

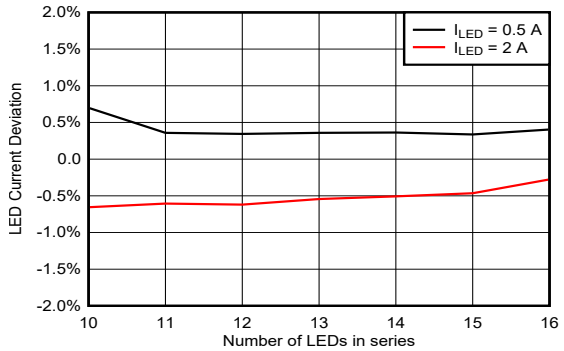

Figure 5-4. LED Current Deviation vs. Number of LEDs in Series in Analog Dimming Mode

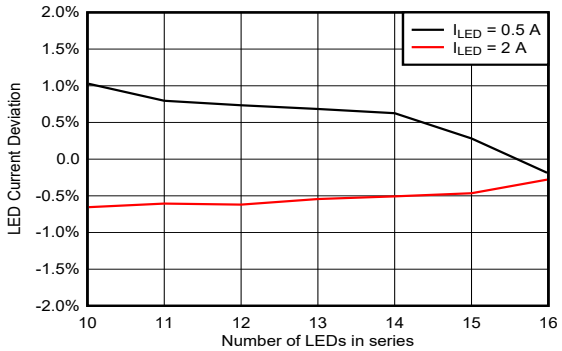

Figure 5-5. LED Current Deviation vs. Number of LEDs in Series in PWM Dimming Mode

5.4 Analog Dimming Performance

Figure 5-6 gives the test result of linearity of analog dimming, in comparison with the theoretical value. Input voltage is 24V, with 15 White LEDs in series used as load. The full-scale LED current is set at 2A. The frequency of the input PWM signal at the ADIM/HD pin is 20kHz.

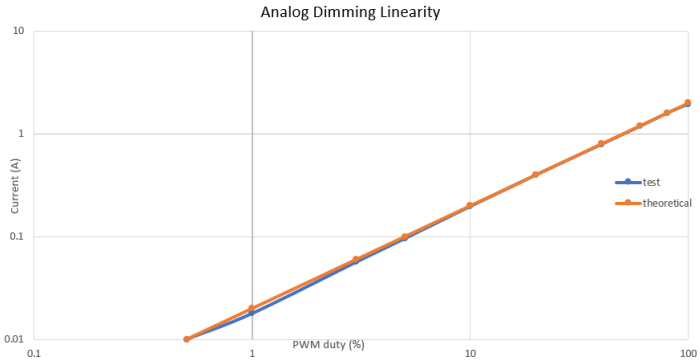

Figure 5-6. Analog Dimming Linearity

5.5 PWM Dimming Performance

Figure 5-7, Figure 5-8, and Figure 5-9 show the PWM dimming waveforms at 10%, 50%, and 90% duty cycles, respectively. Input voltage is 24V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2A. The frequency of the input PWM signal at the PWM/EN pin is 20kHz.

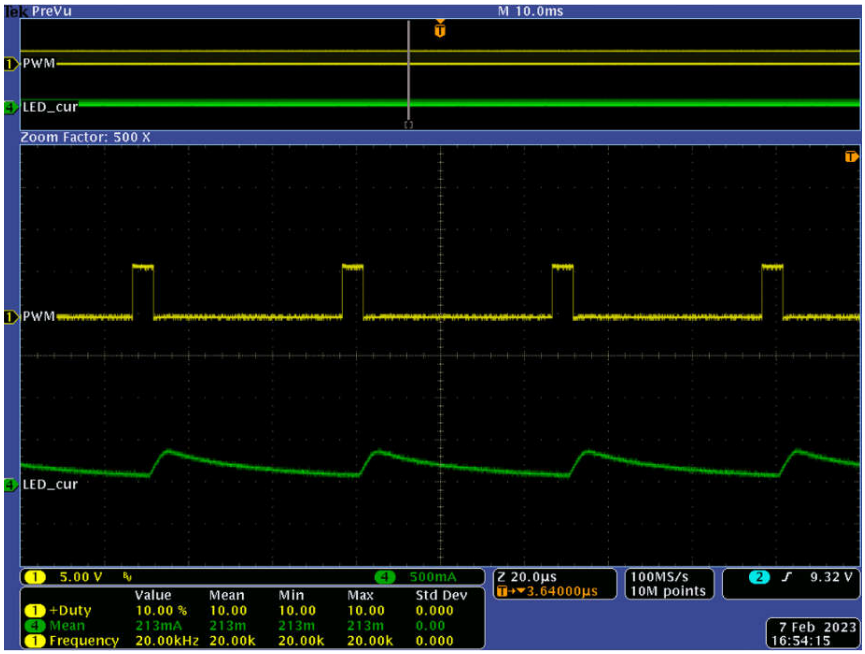

Figure 5-7. Waveforms at 10% Duty Cycle, 20kHz PWM Dimming

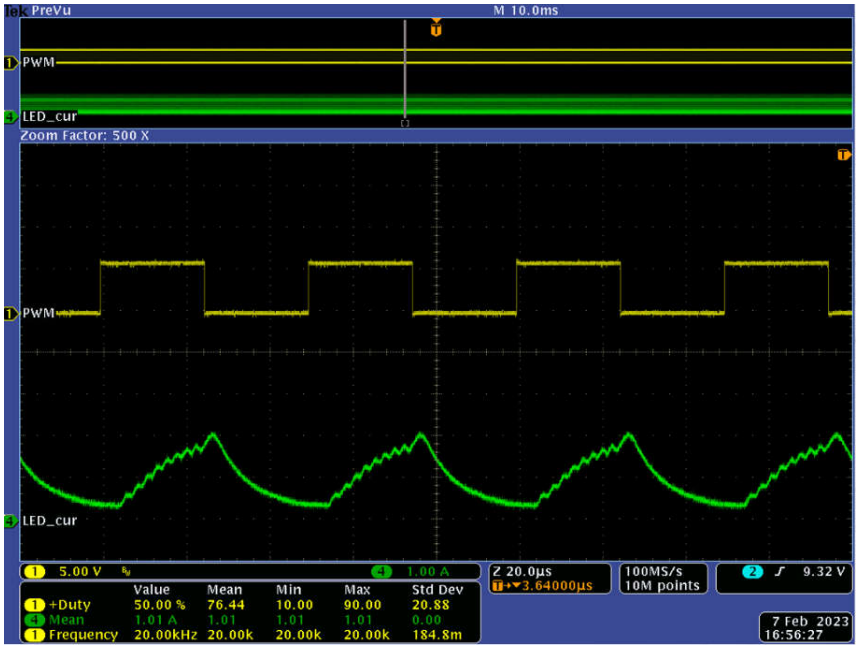

Figure 5-8. Waveforms at 50% Duty Cycle, 20kHz PWM Dimming

Figure 5-9. Waveforms at 90% Duty Cycle, 20kHz PWM Dimming

Figure 5-10 gives the test result of linearity of PWM dimming, in comparison with the theoretical value. Input voltage is 24V, with 16 white LEDs in series used as load. The full-scale LED current is set at 2A. The frequency of the input PWM signal at the PWM/EN pin is 20kHz.

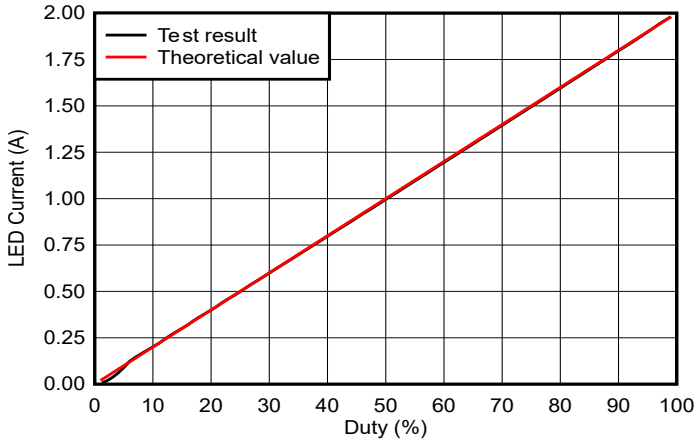

Figure 5-10. PWM Dimming Linearity

5.6 Hybrid Dimming Performance

Figure 5-11, Figure 5-12 show the hybrid dimming waveforms at 10%, and 20% duty cycles, respectively. Input voltage is 24V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2A. The ADIM/HD pin is always low. The frequency of the input PWM signal at the PWM/EN pin is 20kHz.

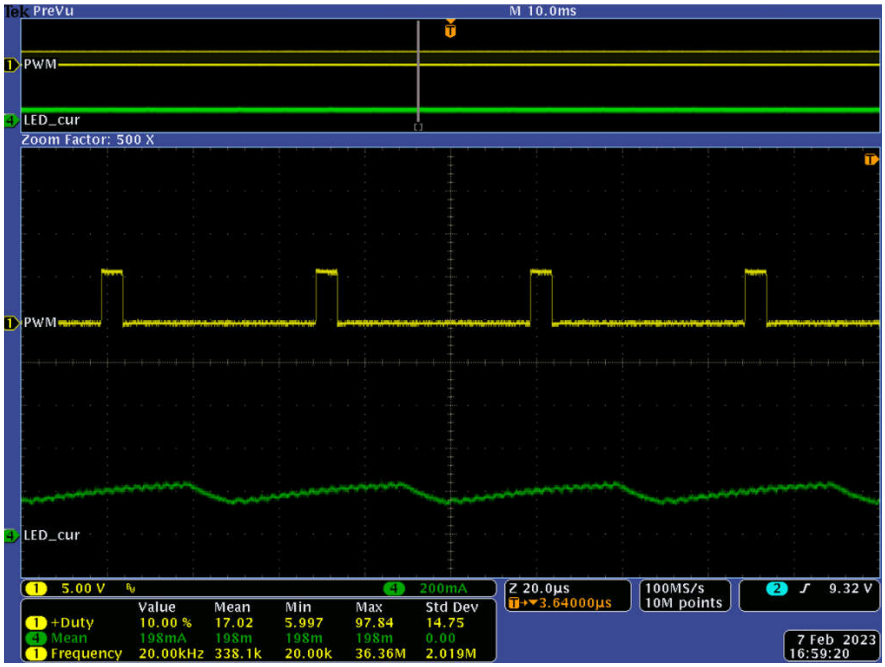

Figure 5-11. Waveforms at 10% Duty Cycle, 20kHz Hybrid Dimming

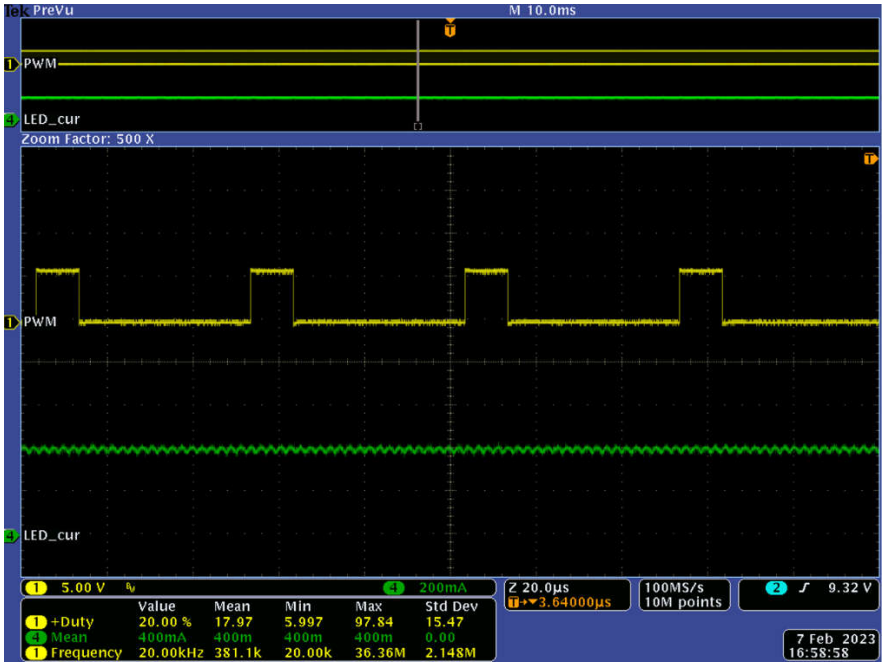

Figure 5-12. Waveforms at 20% Duty Cycle, 20kHz Hybrid Dimming

When the hybrid dimming is enabled, the LED current is regulated by the analog dimming at high brightness level (12.5% ~ 100%) and by the PWM dimming at low brightness level (0%~12.5%).

Figure 5-13 gives the test result of linearity of hybrid dimming, in comparison with the theoretical value. Input voltage is 24V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2A. The frequency of the input PWM signal at the PWM/EN pin is 20kHz.

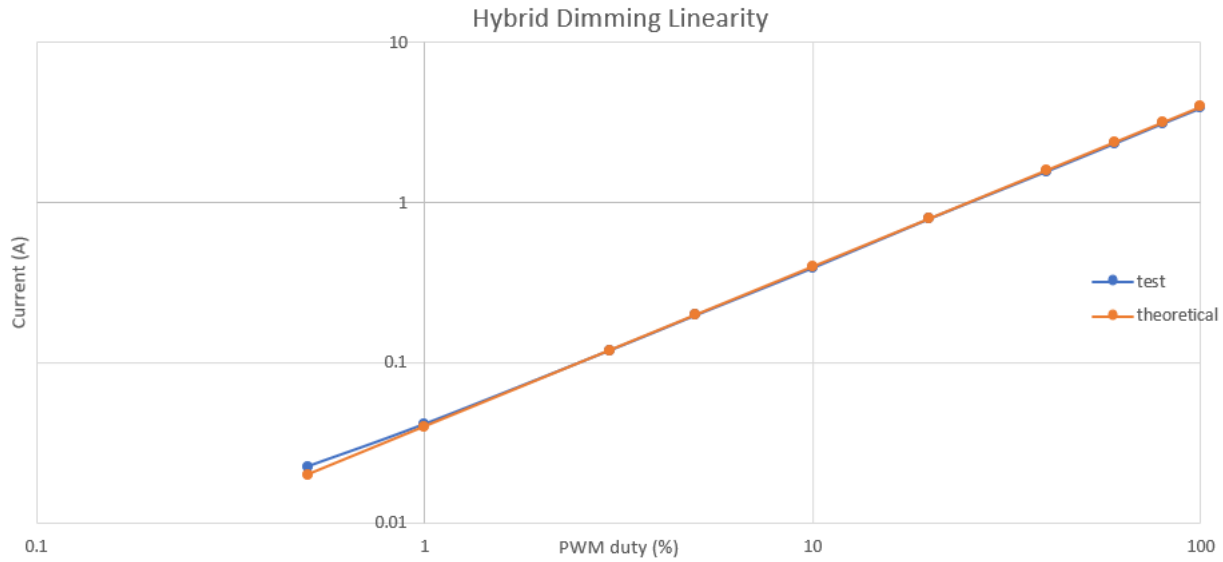

Figure 5-13. Hybrid Dimming Linearity

5.7 Flexible Dimming Performance

Figure 5-14, Figure 5-15 and Figure 5-16 show the flexible dimming waveforms at different ADIM/HD pin and PWM/EN pin input duty cycles. Input voltage is 24V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2A. The frequency of the input PWM signal at the ADIM/HD pin and PWM/EN pin is 20kHz.

Figure 5-14. Waveforms at 50% Duty Cycle ADIM/HD and 50% Duty Cycle PWM/EN

Figure 5-15. Waveforms at 10% Duty Cycle ADIM/HD and 90% Duty Cycle PWM/EN

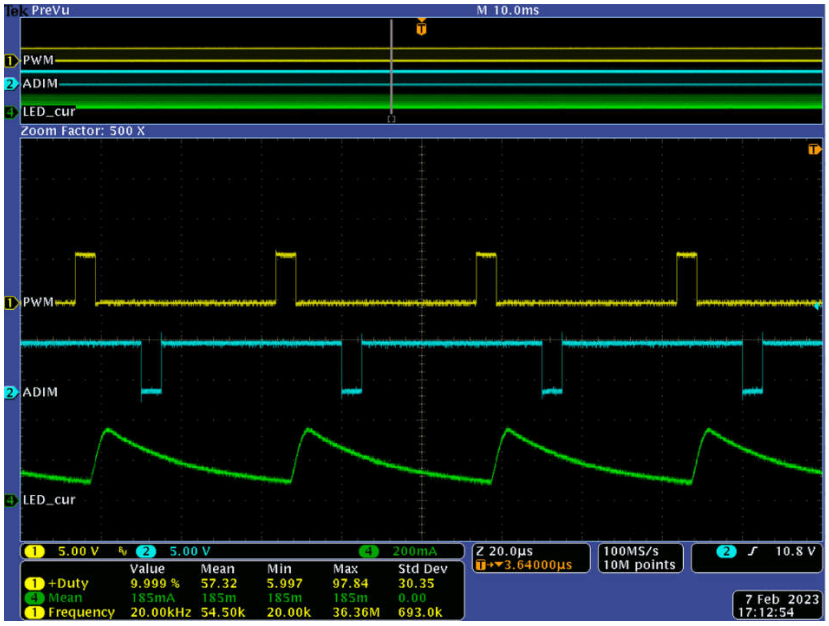

Figure 5-16. Waveforms at 90% Duty Cycle ADIM/HD and 10% Duty Cycle PWM/EN

6 Schematic

Figure 6-1 shows the schematic for TPS923655DMTREVM. The only difference between TPS923655DMTREVM, TPS923655DRRREVM and TPS923653DYYREVM schematic is the main LED driver IC.

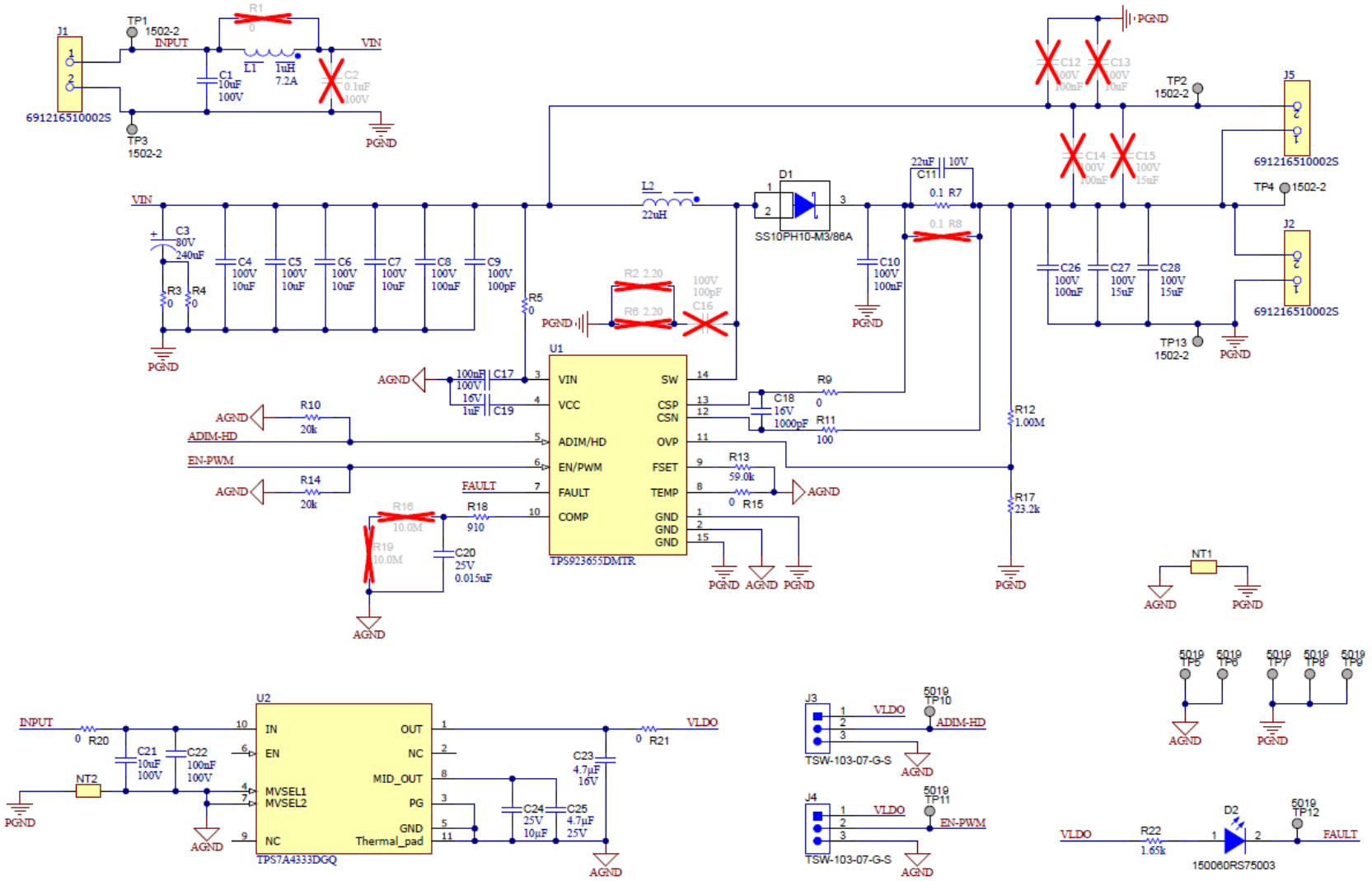

Figure 6-1. TPS923655DMTREVM Schematic

7 Layout

Figure 7-1, Figure 7-2, Figure 7-3 and Figure 7-4 show the layout of the TPS923655DMTREVM printed circuit board (PCB). The layout of TPS923655DMTREVM, TPS923655DRRREVM and TPS923653DYYREVM is almost similar except the LED driver IC.

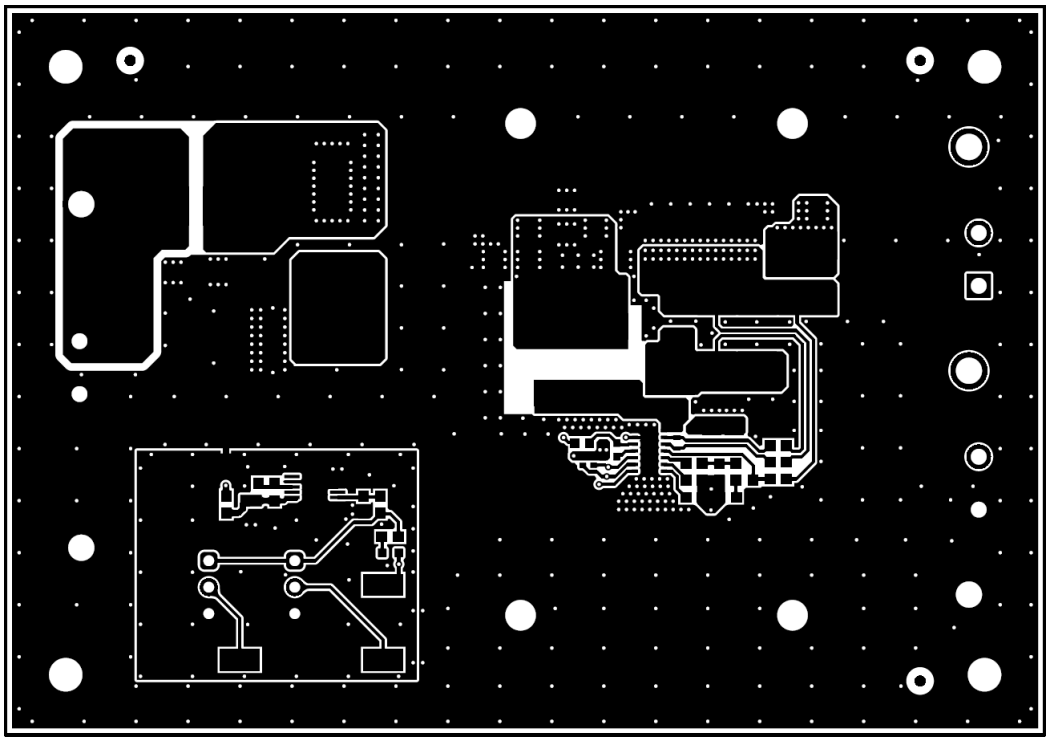

Figure 7-1. TPS923655DMTREVM Top Layer

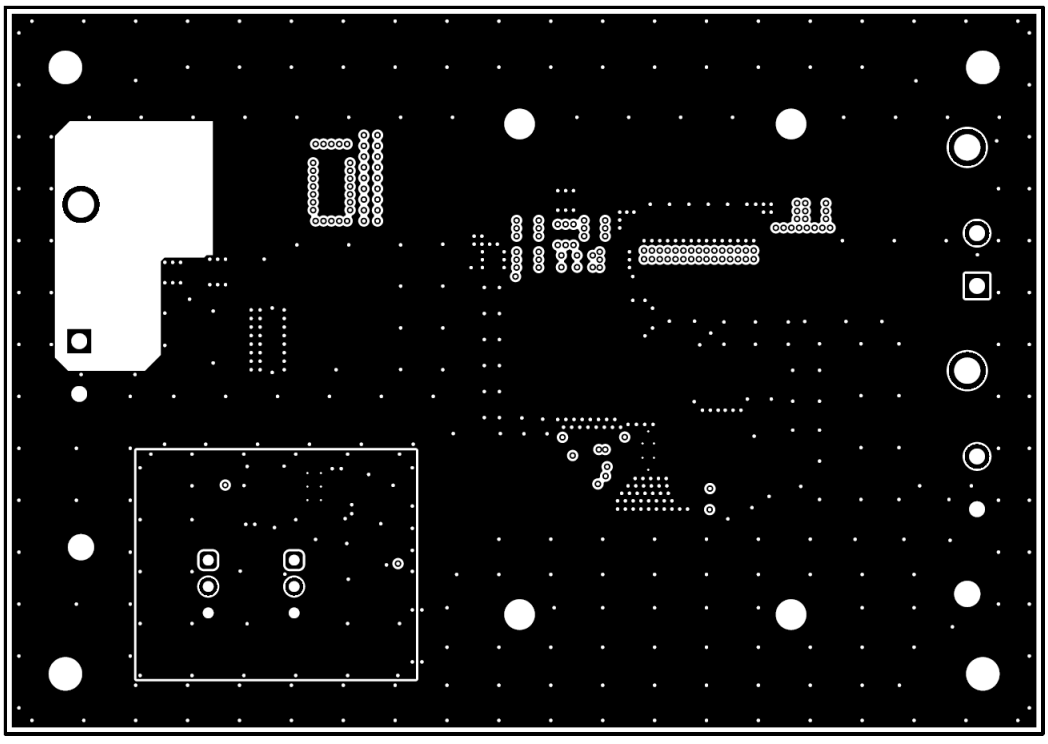

Figure 7-2. TPS923655DMTREVM Inner Layer 1

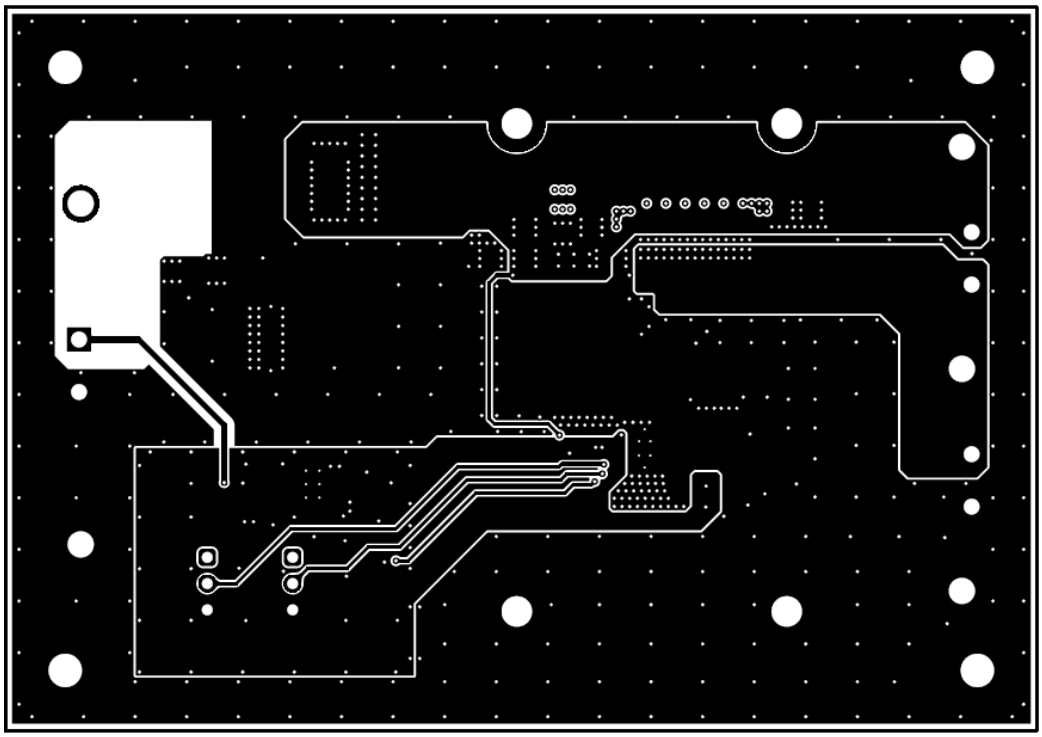

Figure 7-3. TPS923655DMTREVM Inner Layer 2

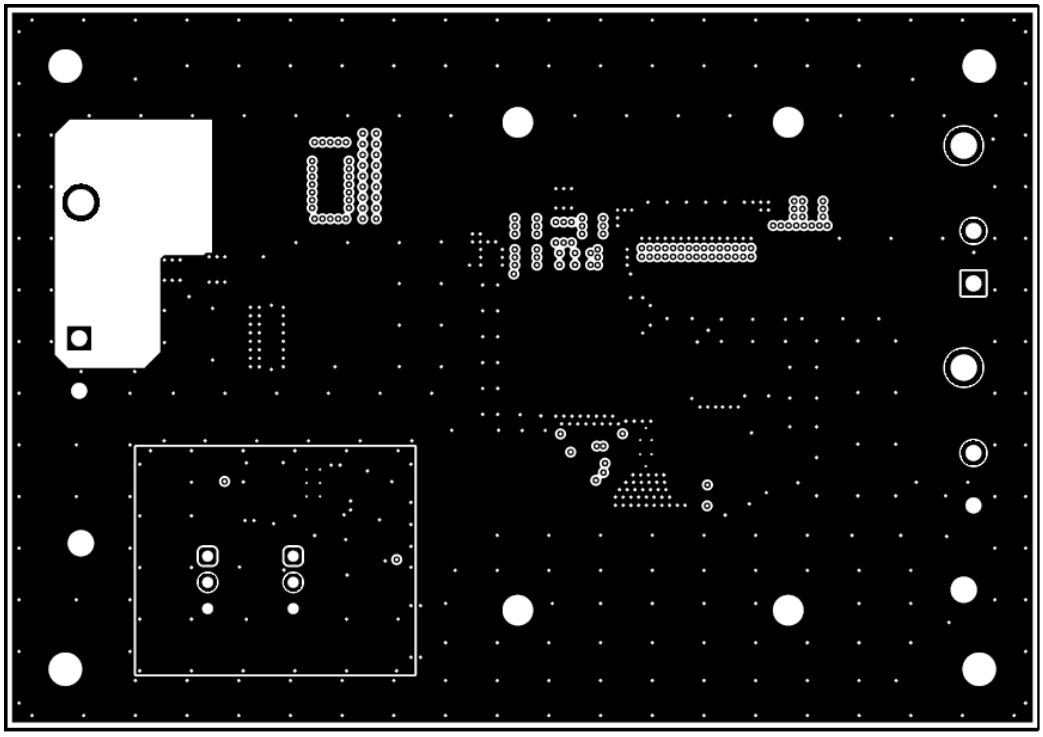

Figure 7-4. TPS923655DMTREVM Bottom Layer

8 Bill of Materials

Table 8-1 shows the bill of materials for TPS92365xEVM.

Table 8-1. TPS92365xEVM Bill of Materials

Designator	Qty.	Description	Part Number	Manufacturer
C1, C4, C5, C6, C7, C21	6	Capacitor Ceramic 10µF ±10% 100V X7S 1210 (3225 Metric)	GRM32EC72A106KE05L	Murata
C3	1	Capacitor Aluminum Electrolytic Radial, Can - SMD 130mΩ at 100kHz 5000 hrs at 125°C 240µF 80V	EMHS800ARA241MKG5S	United Chemi-Con
C8, C10, C17, C26	4	Capacitor Ceramic Chip Multilayer for general purpose, 0603, 0.10µF, X7R, 15%, 10%, 100V	GRM188R72A104KA35J	Murata
C9	1	Capacitor Ceramic for automotive 100pF ±5% 100VDC C0G 0603 Paper T/R	GCM1885C2A101JA16J	Murata
C11	1	Capacitor Ceramic, 22µF, 10V, ±10%, X7R, 1206	GRM31CR71A226KE15L	MuRata
C18	1	Capacitor Ceramic, 1000 pF, 16V, ±10%, X7R, 0402	GRM155R71C102KA01D	MuRata
C19	1	Capacitor Ceramic, 1µF ±10% 16V X7S 0603 (1608 Metric)	GRM188C71C105KA12D	Murata
C20	1	Capacitor Ceramic, 0.015µF, 25V, ±5%, C0G/NP0, 0603	C0603C153J3GACTU	Kemet
C22	1	Capacitor Ceramic, 0.1µF, 100V, ±10%, X7R, 0603	GRM188R72A104KA35J	MuRata
C23	1	CAP, CERM, 4.7µF, 16V, ±10%, X7R, 0603	GRM188Z71C475KE21D	MuRata
C24	1	Capacitor Ceramic, 10µF, 25V,±10%, X5R, 0603	GRM188R61E106KA73D	MuRata
C25	1	Capacitor Ceramic, 4.7µF, 25V,±10%, X6S, AEC-Q200 Grade 2, 0603	GRT188C81E475KE13D	MuRata
C27, C28	2	Capacitor Ceramic, 15µF 100V X7R ±15% SMD 2220 +125°C Emboss T/R	KRM55WR72A156MH01K	Murata
D1	1	Diode, Schottky, 100V, 10A, AEC-Q101, TO-277A	SS10PH10-M3/86A	Vishay-Semiconductor
D2	1	Red 625nm LED indication - discrete 2V 0603 (1608 metric)	150060RS75003	Wurth Electronics
J1, J2, J5	3	2 Position wire to board Terminal block horizontal with board 0.200" (5.08mm) through hole CONN_TERM_BLOCK2	691216510002S	Wurth Elektronics
J3, J4	2	Header, 100mil, 3x1, gold, TH	TSW-103-07-G-S	Samtec
L1	1	Power Inductor WE-MAPI SMT, size 4020, 1µH, 7.2A, 15mΩ	74438356010	Wurth Elektronik
L2	1	Power Inductor SMT 22µH ±20% 9.7A 23.65mΩ max. SMD2	74439369220	Wurth
LBL1	1	Thermal transfer printable labels, 1.250" W x 0.250" H - 10,000 per roll	THT-13-457-10	Brady
R3, R4	2	Resistor, 0, 5%, 0.25W, 1206	RC1206JR-070RL	Yageo America
R5, R9, R15, R20, R21	5	Resistor, 0, 5%, 0.1W, 0603	RC0603JR-070RL	Yageo
R7	1	Resistor chip, 100 mΩ ±0.5% 2W 2512 (6432 Metric) current sense metal film	PCS2512DR1000ET	Ohmite
R10, R14	2	Resistor chip, 20.0kΩ ±1% 0.063W, 1/16W 0402 (1005 metric) moisture resistant thick film	RC0402FR-0720KL	Yageo
R11	1	Resistor chip, 100Ω, 1%, 0.1W, 0603	RC0603FR-07100RL	Yageo
R12	1	Resistor, 1.00M, 1%, 0.1W, 0603	RC0603FR-071ML	Yageo
R13	1	Resistor, 59.0kΩ, 1%, 0.1W, 0603	RC0603FR-0759KL	Yageo
R17	1	Resistor, 23.2kΩ, 1%, 0.1W, 0603	RC0603FR-0723K2L	Yageo
R18	1	Resistor, 910Ω, 1%, 0.1W, 0603	RC0603FR-07910RL	Yageo
R22	1	Resistor, 1.65kΩ, 1%, 0.1W, 0603	RC0603FR-071K65L	Yageo
SH-J1, SH-J2	2	Shunt, 2.54mm, gold, black	60900213421	Wurth Elektronik
TP1, TP2, TP3, TP4, TP13	5	Terminal, turret, TH, double	1502-2	Keystone
TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12	8	Test point, miniature, SMT	5019	Keystone
U1	1	65V 4- LED Driver with Flexible Dimming VSON14	TPS923655DMTR	Texas Instruments
U2	1	LDO, Fixed Output, Dual, 3.3V, 10/12/15V, 50mA, Precision Enable, Power-Good, HVSSOP10	TPS7A4333DGQ	Texas Instruments

9 Additional Information

Trademarks

All trademarks are the property of their respective owners.

10 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (June 2023) to Revision B (October 2024)	Page
• Changed function description for connectors	4
• Changed description of power supply input connection terminal and LED load connection terminal	5
• Changed figure of TPS923655DMTREVM schematic	14
• Changed figure of TPS923655DMTREVM layout	15
• Updated Bill of Materials	17

Changes from Revision * (May 2023) to Revision A (June 2023)	Page
• Changed function description for connectors	4
• Changed power supply input connection terminal	5
• Changed PWM input pin name	5

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

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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.

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