User's Guide

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

ABSTRACT

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).

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Trademarks

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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 2-A/4-A non-synchronous boost/buck-boost LED driver and features a wide input voltage range (4.5-V to 65-V) 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 datasheet.

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} = 24 V, 15 white LEDs, 2-A output current		100		mApp
Analog dimming range	3.3-V PWM at ADIM/HD pin	1		100	%
Analog dimming frequency		0.1		100	kHz
PWM dimming range	3.3-V PWM at PWM/EN pin	1		100	%
PWM dimming frequency		0.1		50	kHz
Switching frequency			400		kHz
Efficiency	V_{IN} = 24 V, 15 white LEDs, 2-A 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	test point of external LDO output V_{LDO}
J2	connect to LED load (make sure the LED load has a maximum current rating larger than 2 A)
J3	SW test point
J4	PWM/EN optional connection to V_{LDO} or GND
J5	OVP test point
J6	FAULT test point
J7	ADIM/HD optional connection to V_{LDO} or GND
J8	compensation capacitor test point
J9, J10, J11, J12	GND test point
TP1	V_{IN} power input
TP2	V_{IN} test point
TP3	test point of the anode of LED load
TP4	power connection to the anode of LED load
TP7	GND test point
TP8, TP14	GND power connection
TP9	PWM/EN signal input
TP10	PWM/EN test point
TP11	VCC test point
TP12	ADIM/HD signal input
TP13	ADIM/HD test point

4.2 Input/Output Connection

A power supply capable of supplying 4 A must be connected to TP1 (VIN) and TP14 (GND) through a pair of 20-AWG wires. The LED load must be connected to TP4 & TP8 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 TP8 or J2 terminal beside TP8. Wires should be twisted and kept as short as possible to minimize voltage drop, inductance, and EMI transmission.

TP9 and TP12 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 1.2 V, typically 3.3 V. The dimming frequency should be in the range of 0.1 kHz and 50 kHz for PWM signal at PWM/EN pin. While for PWM signal on ADIM/HD pin, dimming frequency should be within 0.1 kHz and 100 kHz.

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 2 A. The frequency of the input PWM signal at the ADIM/HD pin is 20 kHz. Input voltage V_{IN} is 24 V. 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 2 A. The frequency of the input PWM signal at the PWM/EN pin is 20 kHz. Input voltage V_{IN} is 24 V. The load is 16 white LEDs in series.

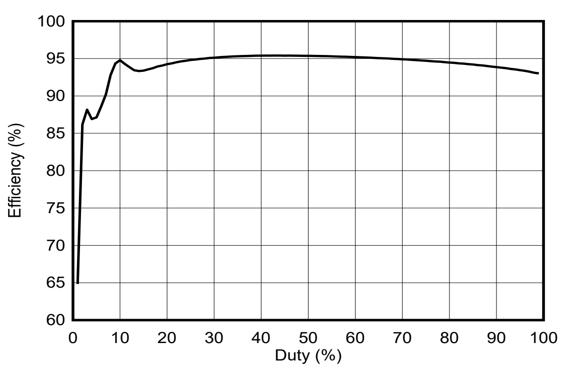

Figure 5-1. Efficiency vs. Input Duty Cycle in Analog Dimming Mode

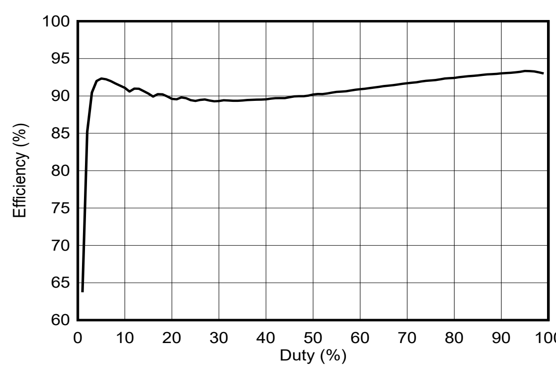

Figure 5-2. Efficiency vs. Input Duty Cycle in PWM Dimming Mode

5.2 Line Regulation

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

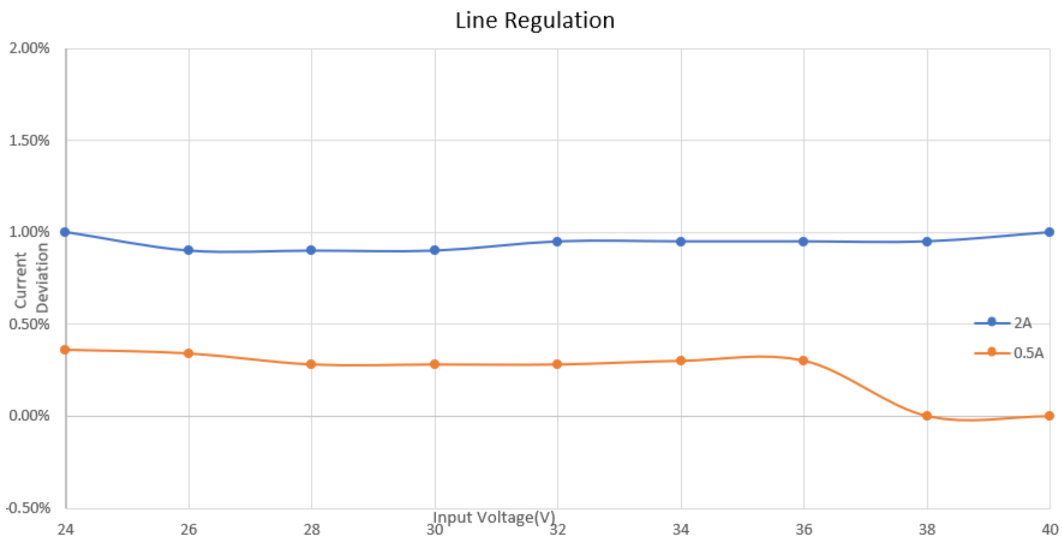

Figure 5-3. LED Current Deviation vs. Input Voltage

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 24 V. LED current is set at 0.5 A and 2 A 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 20 kHz.

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 24 V. LED current is set at 0.5 A and 2 A 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 20 kHz.

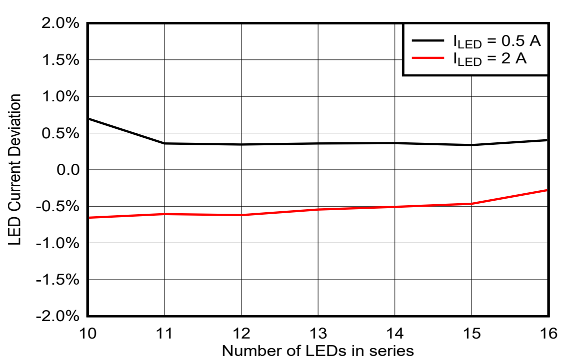

Figure 5-4. LED Current Deviation vs. Number of LEDs in Series in Analog Dimming Mode

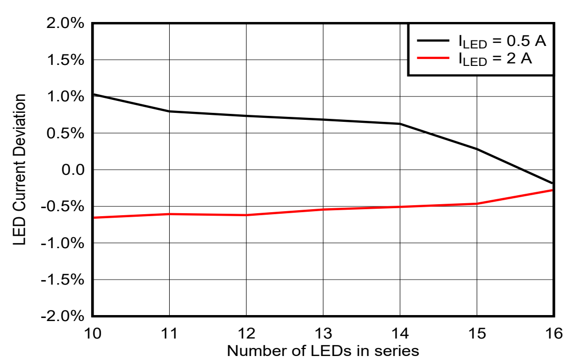

Figure 5-5. LED Current Deviation vs. Number of LEDs in Series in PWM Dimming Mode

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 24 V, with 15 White LEDs in series used as load. The full-scale LED current is set at 2 A. The frequency of the input PWM signal at the ADIM/HD pin is 20 kHz.

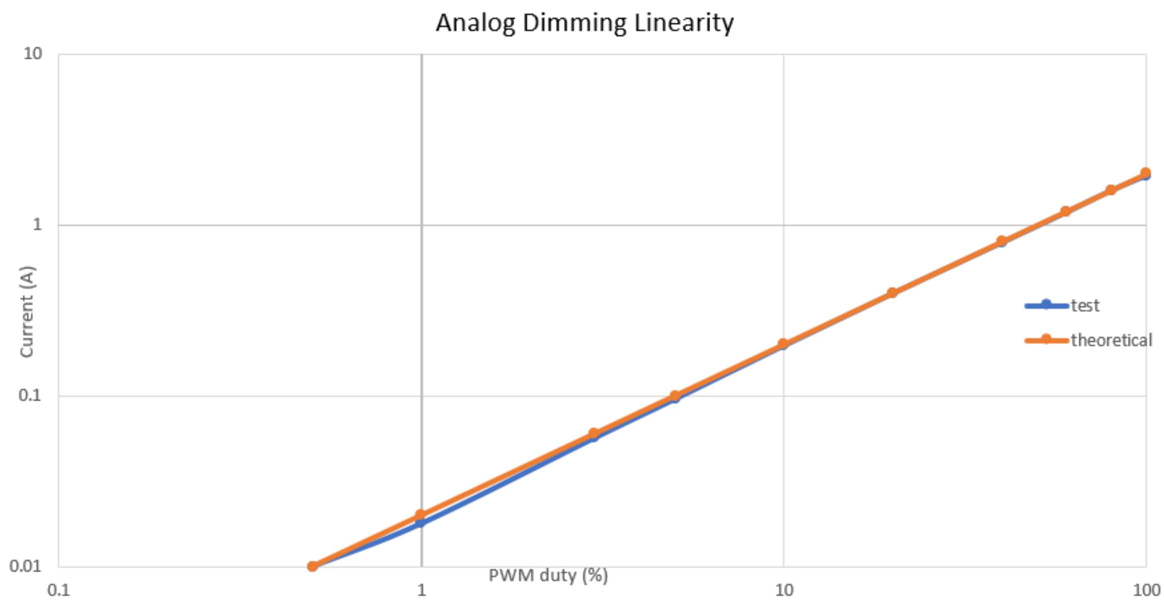

Figure 5-6. Analog Dimming Linearity

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 24 V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2 A. The frequency of the input PWM signal at the PWM/EN pin is 20 kHz.

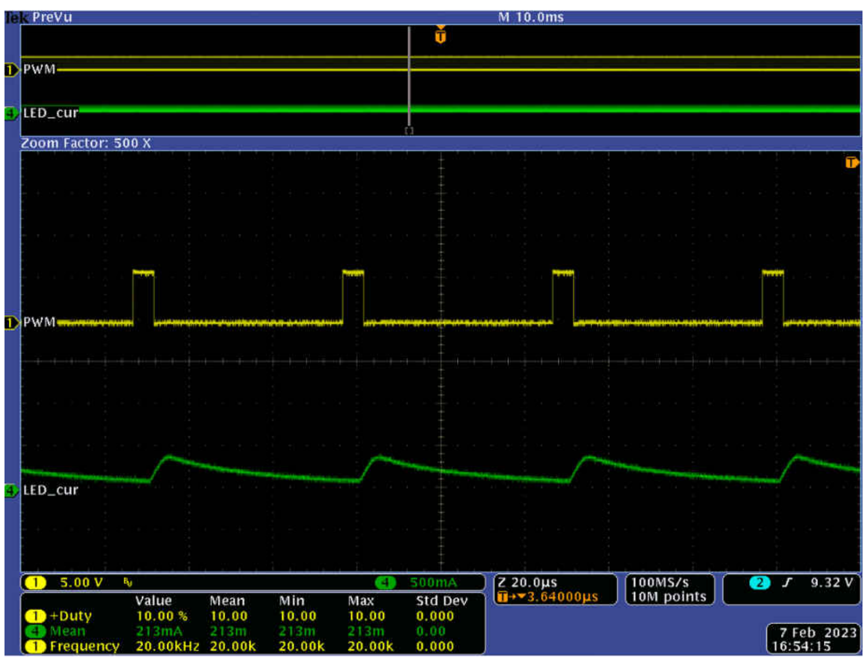

Figure 5-7. Waveforms at 10% Duty Cycle, 20 kHz PWM Dimming

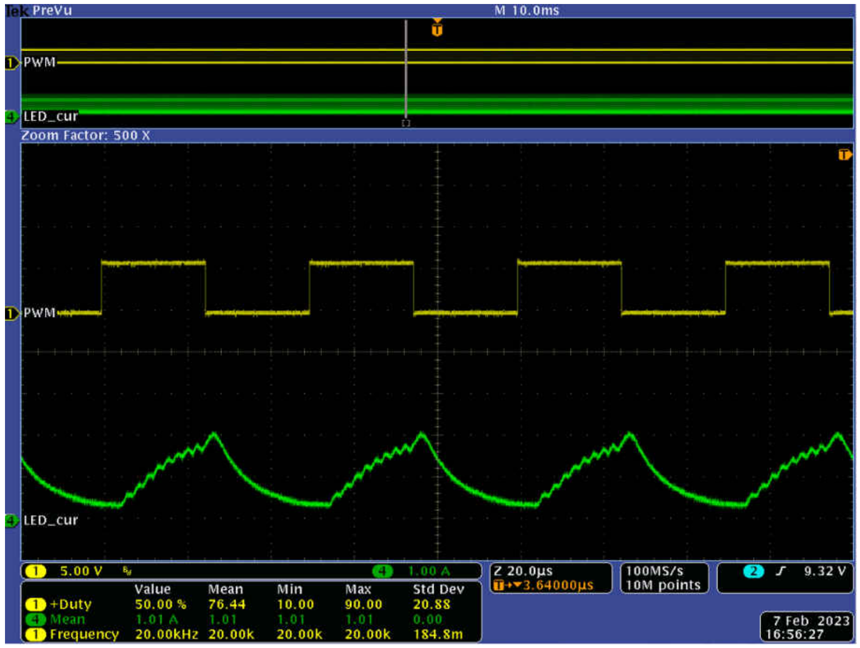

Figure 5-8. Waveforms at 50% Duty Cycle, 20 kHz PWM Dimming

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

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

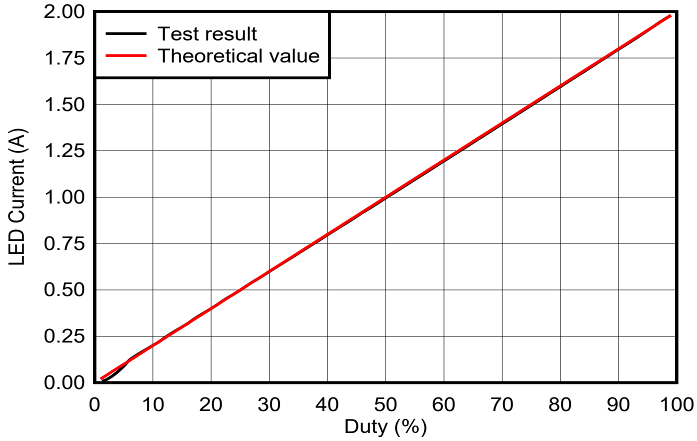

Figure 5-10. PWM Dimming Linearity

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 24 V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2 A. The ADIM/HD pin is always low. The frequency of the input PWM signal at the PWM/EN pin is 20 kHz.

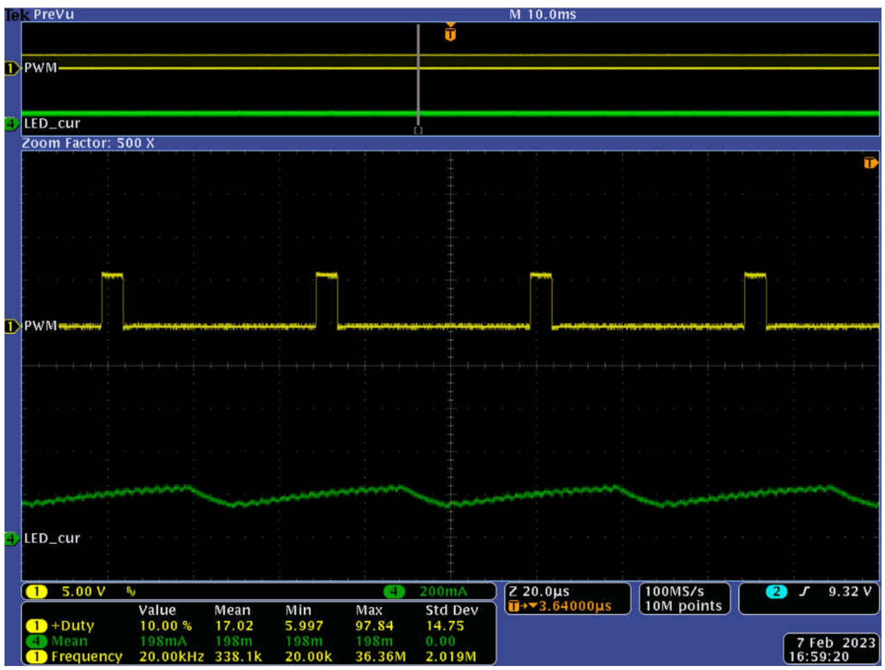

Figure 5-11. Waveforms at 10% Duty Cycle, 20 kHz Hybrid Dimming

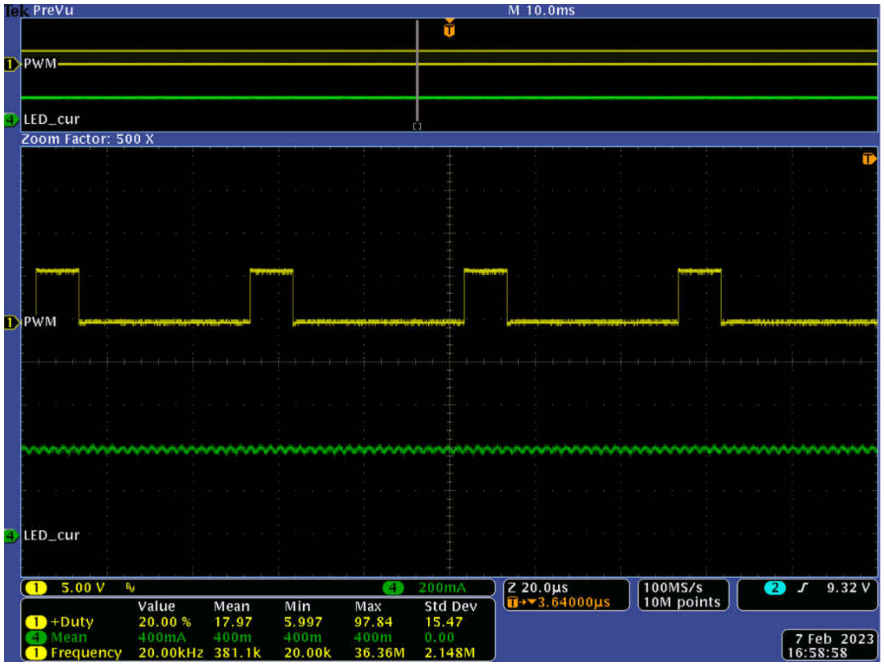

Figure 5-12. Waveforms at 20% Duty Cycle, 20 kHz Hybrid Dimming

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 24 V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2 A. The frequency of the input PWM signal at the PWM/EN pin is 20 kHz.

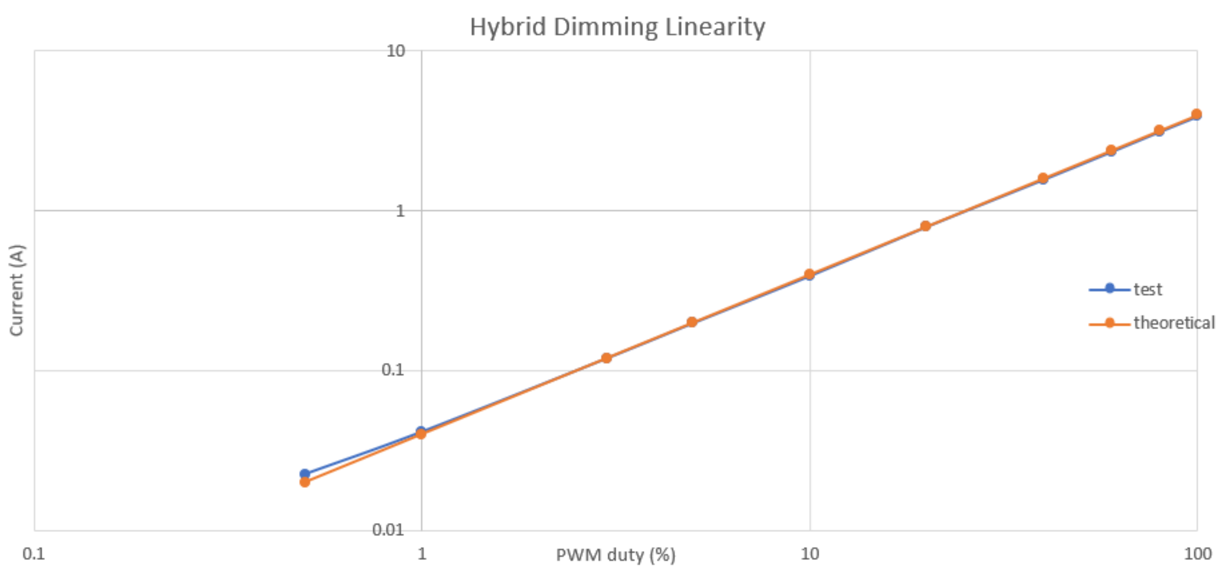

Figure 5-13. Hybrid Dimming Linearity

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 24 V, with 15 white LEDs in series used as load. The full-scale LED current is set at 2 A. The frequency of the input PWM signal at the ADIM/HD pin and PWM/EN pin is 20 kHz.

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.

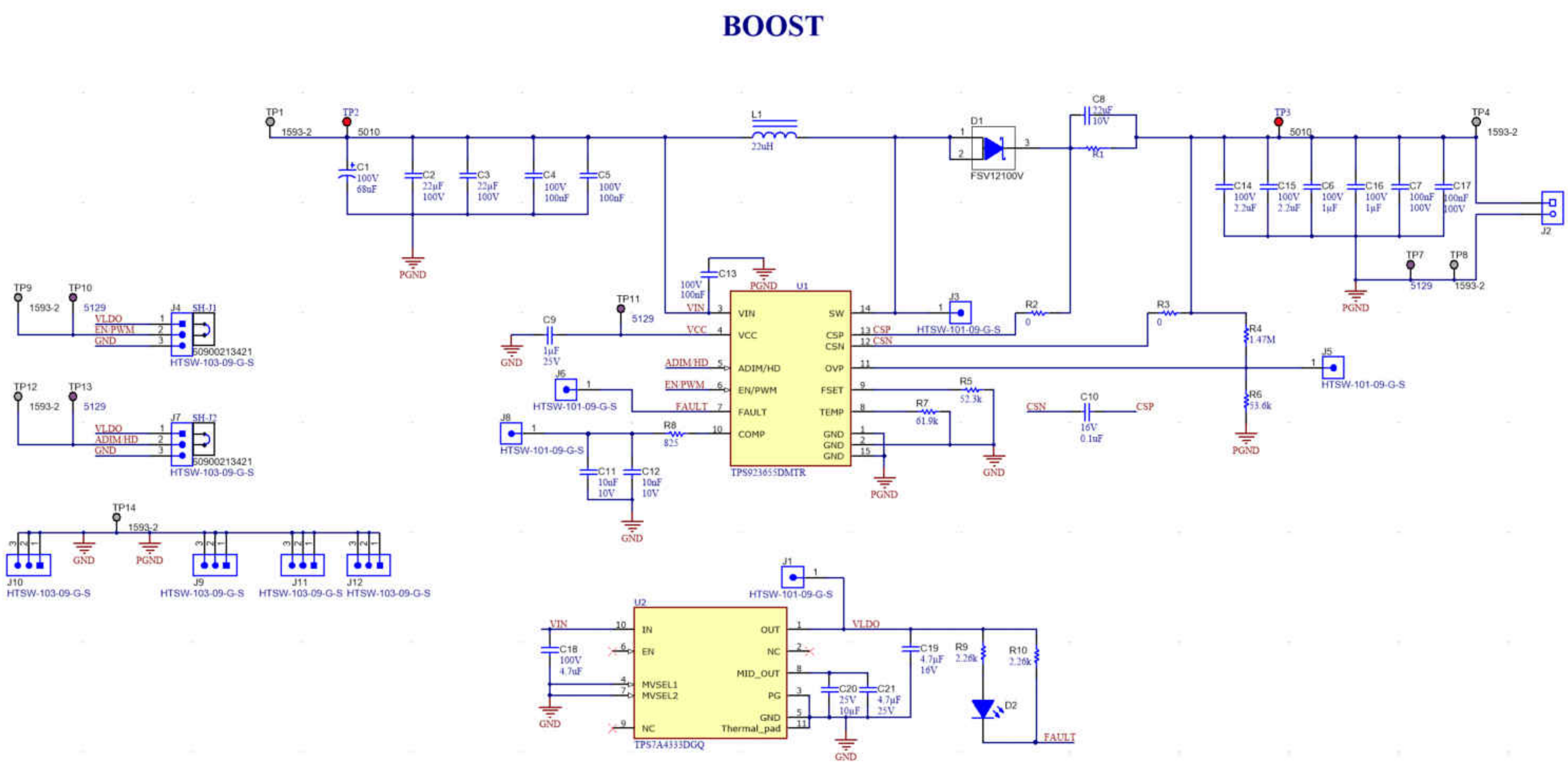

Figure 6-1. TPS923655DMTREVM Schematic

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 only difference between TPS923655DMTREVM, TPS923655DRRREVM and TPS923653DYYREVM PCB layout is the main LED driver IC.

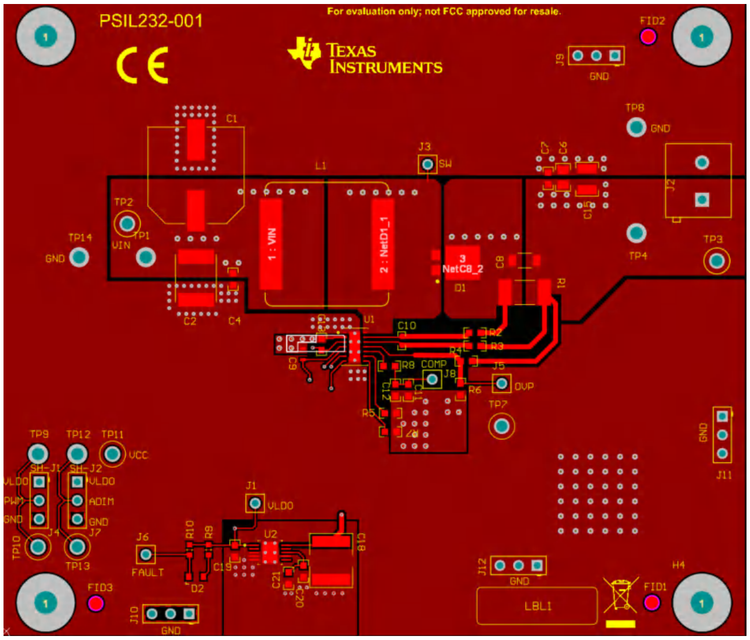

Figure 7-1. TPS923655DMTREVM Top Layer

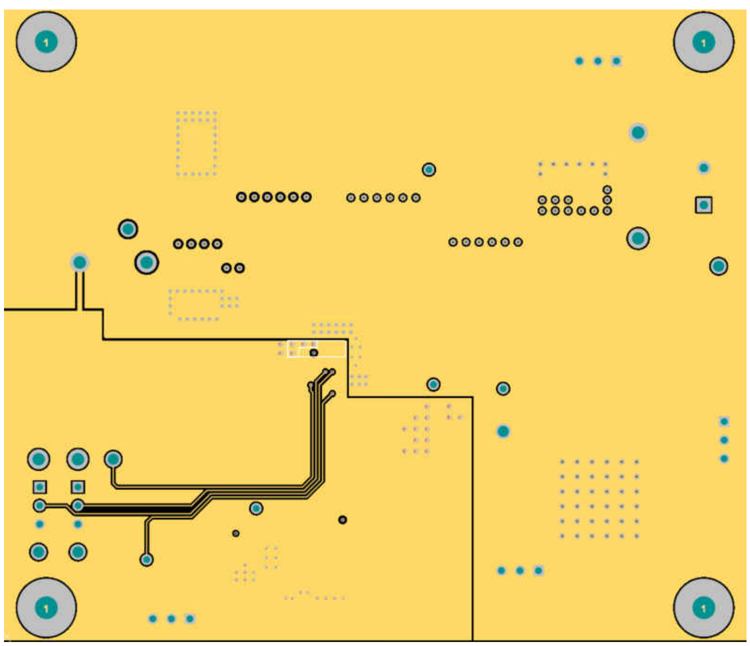

Figure 7-2. TPS923655DMTREVM Inner Layer 1

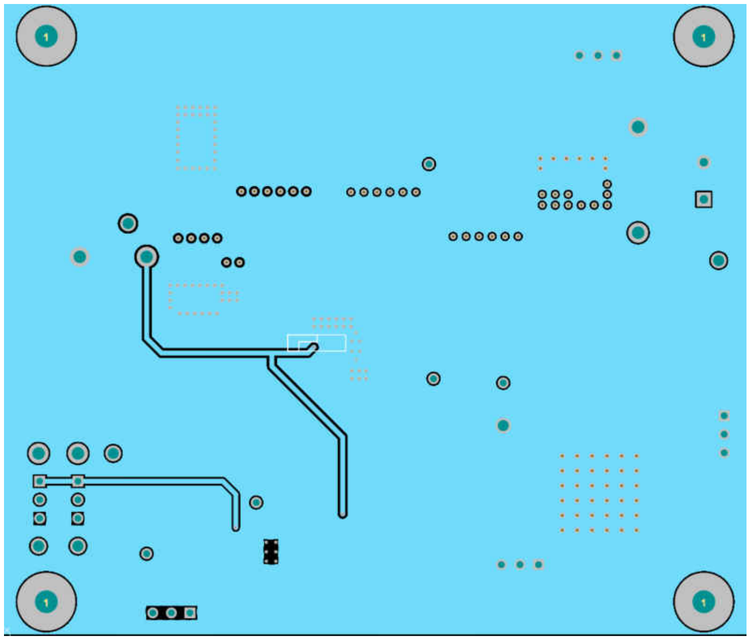

Figure 7-3. TPS923655DMTREVM Inner Layer 2

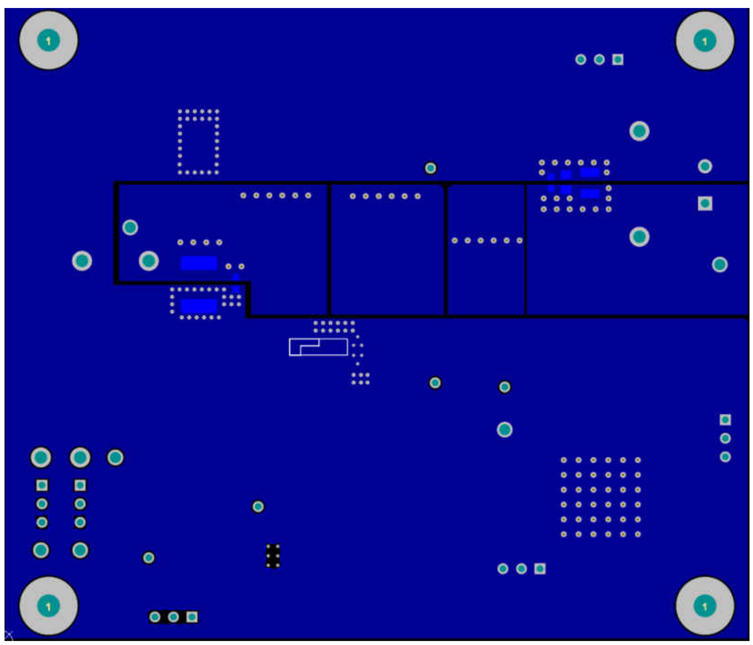

Figure 7-4. TPS923655DMTREVM Bottom Layer

8 Bill of Materials

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

Table 8-1. TPS92365xEVM Bill of Materials

Designator	Qty.	Value	Description	Package	Part Number	Manufacturer
C1	1	68 uF	CAP, AL, 68 uF, 100 V, +/- 20%, 0.26 ohm, SMD	CAPSMT_62_KG5	EMVH101ARA680MKG5S	Chemi-Con
C2, C3	2	22 µF	CAP, CERM, 22 µF, VAC/100 VDC,+/- 20%, X7S, 6x5x5mm	CKG57N	CKG57NX7S2A226M500JJ	TDK
C4, C5, C7, C13, C17	5	0.1 uF	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A104KA35D	MuRata
C6, C16	2	1 µF	CAP, CERM, 1 µF, 100 V,+/- 10%, X7S, 0805	0805	C2012X7S2A105K125AE	TDK
C8	1	22 uF	CAP, CERM, 22 uF, 10 V, +/- 10%, X7R, 1206	1206	LMK316AB7226KL-TR	Taiyo Yuden
C9	1	1 µF	CAP, CERM, 1 µF, 25 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E1X7R1E105K080AC	TDK
C10	1	0.1 uF	CAP, CERM, 0.1 uF, 16 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	0402	C0402C104K4RACAUTO	Kemet
C11, C12	2	0.01 uF	CAP, CERM, 0.01 uF, 10 V, +/- 10%, X7R, 0603	0603	0603ZC103KAT2A	AVX
C14, C15	2	2.2 uF	CAP, CERM, 2.2 uF, 100 V, +/- 10%, X7R, 1210	1210	HMK325B7225KN-T	Taiyo Yuden
C19	1	4.7 uF	CAP, CERM, 4.7 uF, 16 V,+/- 10%, X7R, 0603	0603	GRM188Z71C475KE21D	MuRata
C18	1	4.7 uF	CAP, CERM, 4.7 uF, 100 V, +/- 10%, X7R, AEC-Q200 Grade 1	2220	CGA9N2X7R2A475K230KA	TDK
C20	1	10 µF	CAP, CERM, 10 µF, 25 V,+/- 10%, X5R, 0603	0603	GRM188R61E106KA73D	MuRata
C21	1	4.7 µF	CAP, CERM, 4.7 µF, 25 V,+/- 10%, X6S, AEC-Q200 Grade 2, 0603	0603	GRT188C81E475KE13D	MuRata
D1	1		Diode, Schottky, 100 V, 12 A, AEC-Q101, TO-277A	TO-277A	FSV12100V	Fairchild Semiconductor
D2	1		LED, Super Red, SMD	VLMx0_Red	VLMS20J2L1-GS08	Vishay-Semiconductor
J1, J3, J5, J6, J8	5		Header, 100mil, 1x1, Gold, TH	Samtec_HTSW-101-09-x-S	HTSW-101-09-G-S	Samtec
J2	1		Terminal Block, 5.08 mm, 2x1, Brass, TH	On-Shore_ED120_2DS	ED120/2DS	On-Shore Technology
J4, J7, J9, J10, J11, J12	6		Header, 100mil, 3x1, Gold, TH	Samtec_HTSW-103-09-x-S	HTSW-103-09-G-S	Samtec
L1	1	22 uH	Inductor, Shielded, Powdered Iron, 22 uH, 12 A, 0.0265 ohm, AEC-Q200 Grade 0, SMD	SRP1770TA	SRP1770TA-220M	Bourns
R1	1	0.1	RES, 0.1, 0.5%, 2 W, 2512	2512	PCS2512DR1000ET_2512-MFG	Ohmite
R2, R3	2	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R4	1	1.47 M	RES, 1.47 M, 1%, 0.1 W, 0603	0603	CRCW06031M47FKEA	Vishay-Dale
R5	1	52.3 k	RES, 52.3 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD0752K3L	Yageo America
R6	1	53.6 k	RES, 53.6 k, 0.1%, 0.1 W, 0603	0603	RG1608P-5362-B-T5	Susumu Co Ltd
R7	1	61.9 k	RES, 61.9 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD0761K9L	Yageo America
R8	1	825	RES, 825, 1%, 0.1 W, 0603	0603	CRCW0603825RFKEA	Vishay-Dale
R9, R10	2	2.26 k	RES, 2.26 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06032K26FKEA	Vishay-Dale
SH-J1, SH-J2	2		Shunt, 2.54mm, Gold, Black	Wurth_60900213421	60900213421	Wurth Elektronik
TP1, TP4, TP8, TP9, TP12, TP14	6		Terminal, Turret, TH, Double	Keystone1593-2	1593-2	Keystone
TP2, TP3	2		Test Point, Multipurpose, Red, TH	Keystone5010	5010	Keystone Electronics
TP7, TP10, TP11, TP13	4		Test Point, Multipurpose, Purple, TH	Keystone5129	5129	Keystone Electronics

Table 8-1. TPS92365xEVM Bill of Materials (continued)

Designator	Qty.	Value	Description	Package	Part Number	Manufacturer
U1	1		65-V 2-A/4-A Boost/Buck-Boost LED Driver with Inductive Fast Dimming and spread spectrum	VSON (14), WSON (12), SOT-23-THN (14)	TPS923655DMTR, TPS923655DRRR, TPS923653DYYR	Texas Instruments
U2	1		LDO, Fixed Output, Dual, 3.3V, 10/12/15V, 50mA, Precision Enable, Power-Good, HVSSOP10	HVSSOP10	TPS7A4333DGQ	Texas Instruments

9 Revision History

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

Changes from Revision * (May 2023) to Revision A (June 2023) **Page**