User's Guide

TPS542951 Step-Down Converter Evaluation Module User's Guide

ABSTRACT

This user's guide contains information for the TPS542951EVM-057 evaluation module as well as for the TPS542951. Included are the performance specifications, schematic, and the bill of materials of the TPS542951 EVM.

Table of Contents

List of Figures

List of Tables

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1 Introduction

The TPS542951 is a dual, adaptive on-time, D-CAP2™-mode, synchronous buck converter requiring a low, external component count. The D-CAP2 control circuit is optimized for low-ESR output capacitors such as POSCAP, SP-CAP, or ceramic types and features fast transient response with no external compensation. The switching frequency is internally set at a nominal of 700 kHz. The high-side and low-side switching MOSFETs are incorporated inside the TPS542951 package along with the gate drive circuitry. The low, drain-to-source on-resistance of the MOSFETs allows the TPS542951 to achieve high efficiencies and helps keep the junction temperature low at high-output currents. The TPS542951 also features auto-skip Eco-mode operation for improved light-load efficiency. The TPS542951 dual DC/DC synchronous converter is designed to provide up to 3 A output on CH1 and 3 A output on CH2 from an input voltage source of 4.5 V to 18 V. The output voltage range is from 0.76 V to 7 V. Rated input voltage and output current range for the evaluation module are given in Table 1-1.

The TPS542951 EVM evaluation module is a dual, synchronous buck converter providing 3.3 V at 2 A on CH1 and 1.5 V at 3 A on CH2 from 5 V to 18 V input. This user's guide describes the TPS542951 EVM performance.

Note

Throughout the document, x means 1 or 2, for example, VFBx means VFB1 or VFB2.

Table 1-1. Input Voltage, Output Voltage and Output Current Summary

TPS542951EVM	Input Voltage Range	Output Voltage	Output Current Range
CH1	V_{IN1} = 6 V to 18 V	3.3 V	0 A to 2 A
CH2	V_{IN2} = 5 V to 18 V	1.5 V	0 A to 3 A

2 Performance Specification Summary

A summary of the TPS542951EVM performance specifications is provided in Table 2-1. Specifications are given for an input voltage of V_{INx} = 12 V and an output voltage of 3.3 V and 1.5 V, unless otherwise noted. The ambient temperature is 25°C for all measurement, unless otherwise noted.

Table 2-1. TPS542951EVM Performance Specifications Summary

Specifications		Test Conditions	Min	Typ	Max	Unit
Input voltage range (V_{INx})			(1)	12	18	V
Output voltages	V_{OUT1}			3.3		V
	V_{OUT2}			1.5		
Operating frequency		V_{IN1}, V_{IN2} = 12 V, I_{OUT1} = 1 A, I_{OUT2} = 1.5 A		700		kHz
Output current range	CH1		0		4	A
	CH2		0		2	
Line regulation, V_{OUT1}		I_{OUT1} = 1 A, I_{OUT2} = 0 A, V_{IN1}, V_{IN2}= 6 V to 18 V		+0.25 , -0.55		%
Line regulation, V_{OUT2}		I_{OUT2} = 1.5 A, I_{OUT1} = 0 A, V_{IN1}, V_{IN2}= 5 V to 18 V		+0.15, -0.35		%
Load regulation, V_{OUT1}		V_{IN1}, V_{IN2} = 12 V, I_{OUT1} = 0 A to 2 A		+0.4, -0.1		%
Load regulation, V_{OUT2}		V_{IN1}, V_{IN2} = 12 V, I_{OUT2} = 0 A to 3 A		+0.5, -0.05		%
Over current limit, V_{OUT1}		V_{IN1} = 12 V, L_1 = 2.2 µH	2.7	3.9	4.5	A
Over current limit, V_{OUT2}		V_{IN2} = 12 V, L_1 = 1.5 µH	3.5	4.7	5.4	A
Output ripple voltage, V_{OUT1}		V_{IN1} = 12 V, I_{OUT1} = 2 A		20		mV_{PP}
Output ripple voltage, V_{OUT2}		V_{IN2} = 12 V, I_{OUT2} = 3 A		20		mV_{PP}
Maximum efficiency, V_{OUT1}		V_{IN1} = 6 V, I_{OUT1}= 0.6 A		94.1%		
Maximum efficiency, V_{OUT2}		V_{IN2} = 5 V, I_{OUT2}= 0.5 A		88.8%		

(1) See Table 1-1

3 Modifications

This evaluation module is designed to provide access to the features of the TPS542951. Some modifications can be made to this module.

3.1 Output Voltage Setpoint

To change the output voltages of the EVM, it is necessary to change the value of the top resistor of the feedback divider, R1 or R3. Please refer to the top assembly in Figure 5-1 to locate the resistors close to the output connectors. Changing the value of R1 or R3 can change the output voltage above 0.765 V. The value of R1 or R3 for a specific output voltage can be calculated using Equation 1.

For output voltage from 0.76 V to 7 V:

$$V_{OUT1} = 0.765\ V \times \left(1 + \frac{R1}{R2}\right);\ V_{OUT2} = 0.765\ V \times \left(1 + \frac{R3}{R4}\right) \quad (1)$$

Table 3-1 lists the R1 or R3 values for some common output voltages. For output voltages of 1.8 V or above, a feedforward capacitor (C21 or C20) may be required to improve the phase margin. Pads for this component (C21 or C20) are provided on the printed-circuit board. Note that the resistor values given in Table 3-1 are standard values and not the exact values calculated using Equation 1.

Table 3-1. Output Voltages

Output Voltage (V)	R1, R3 (kΩ)	R2, R4 (kΩ)	C21, C20 (pF)	L1, L2 (µH)	C14, C15, C18 Total Capacitance, C16, C17, C19 Total Capacitance (µF)
1	6.81	22.1		1.5 - 2.2	22 - 68
1.05	8.25	22.1		1.5 - 2.2	22 - 68
1.2	12.7	22.1		1.5 - 2.2	22 - 68
1.5	21.5	22.1		1.5 - 2.2	22 - 68
1.8	30.1	22.1	5 - 22	2.2 - 3.3	22 - 68
2.5	49.9	22.1	5 - 22	2.2 - 3.3	22 - 68
3.3	73.2	22.1	5 - 22	2.2 - 3.3	22 - 68
5	124	22.1	5 - 22	4.7	22 - 68
6.5	165	22.1	5 - 22	4.7	22 - 68

3.2 Output Filter and Closed-Loop Response

The TPS542951 relies on the output filter characteristics to ensure stability of the control loop. The recommended output filter components for common output voltages are given in Table 3-1. It may be possible for other output filter component values to provide acceptable closed-loop characteristics. R11 and R12 are provided for convenience in breaking the control loop and measuring the closed-loop response.

4 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS542951EVM. The section also includes test results typical for the evaluation modules and efficiency, output load regulation, output line regulation, load transient response, output voltage ripple, input voltage ripple, start-up, and switching frequency.

4.1 Input/Output Connections

The TPS542951EVM is provided with input/output connectors and test points as shown in Table 4-1. A power supply capable of supplying 4 A must be connected to J1 through a pair of 20 AWG wires. The loads must be connected to J3 and/or J2 through a pair of 20 AWG wires. The maximum load current capability is 2 times 2 A. Wire lengths must be minimized to reduce losses in the wires. Test point TP1 provides a place to monitor the input voltage (V_{IN}) with TP7 providing a convenient ground reference. TP4 and TP3 are used to monitor the output voltages with TP5 and TP6 as the ground references.

Table 4-1. Connection and Test Points

Reference Designator	Function
J1	V_{IN} (see Table 1-1 for V_{IN} range)
J2	V_{OUT2}, 1.5 V at 3 A maximum
J3	V_{OUT1}, 3.3 V at 2 A maximum
J4	EN1 control. Connect EN1 to off to disable converter 1; connect EN1 to on to enable converter 1.
J5	EN2 control. Connect EN2 to off to disable converter 2; connect EN2 to on to enable converter 2.
JP1	Jumper to give the possibility to use another input voltage for converter 2.
TP1	V_{IN} test point at V_{IN} connector
TP2	V_{IN2} test point after JP1.
TP3	Output voltage test point for converter 2.
TP4	Output voltage test point for converter 1.
TP5, TP6, TP7	Ground test points at input and output connectors.
TP8	EN2 test point.
TP9	EN1 test point.
TP10	Switch node test point of converter 1.
TP11	Switch node test point of converter 2.
TP12	VREG5 test point.
TP13	PG1 test point.
TP14	PG2 test point.
TP15	Analog ground test point.

4.2 Start-Up Procedure

1. Ensure that the jumper at J4 and/or J5 (Enable control) are set from ENx to off.
2. Apply appropriate V_{IN} voltage to VIN and PGND terminals at J1.
3. Move the jumper at J4 and/or J5 (Enable control) to cover ENx and on. The EVM enables the according output voltage.

4.3 Efficiency

4.3.1 Efficiency of Converter 1

Figure 4-1 shows the efficiency for the converter 1 on the TPS542951EVM at an ambient temperature of 25°C.

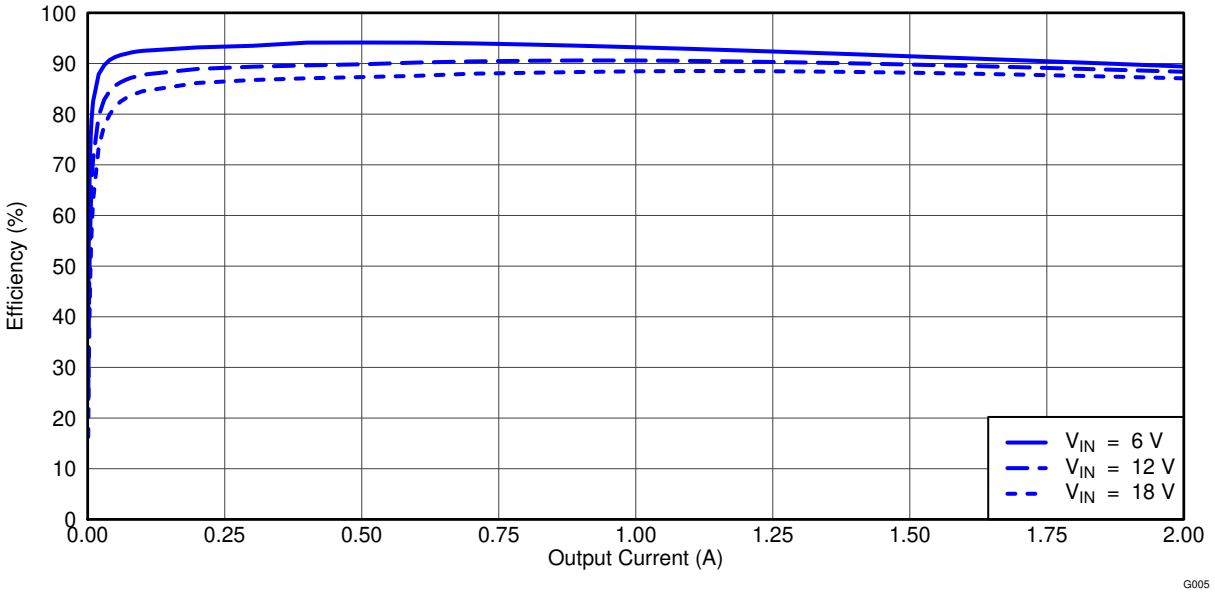

Figure 4-1. TPS542951EVM Converter 1 Efficiency

Figure 4-2 shows the light load efficiency for converter 1 on the TPS542951EVM at an ambient temperature of 25°C.

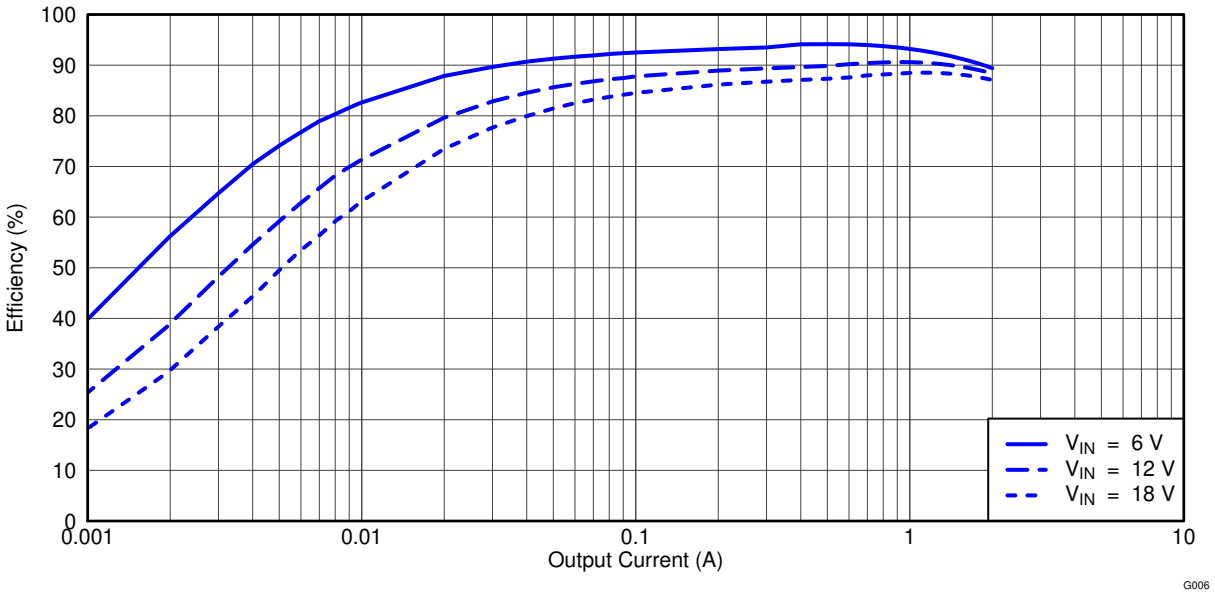

Figure 4-2. TPS542951EVM Converter 1 Light Load Efficiency

4.3.2 Efficiency of Converter 2

Figure 4-3 shows the efficiency for the converter 2 on the TPS542951EVM at an ambient temperature of 25°C.

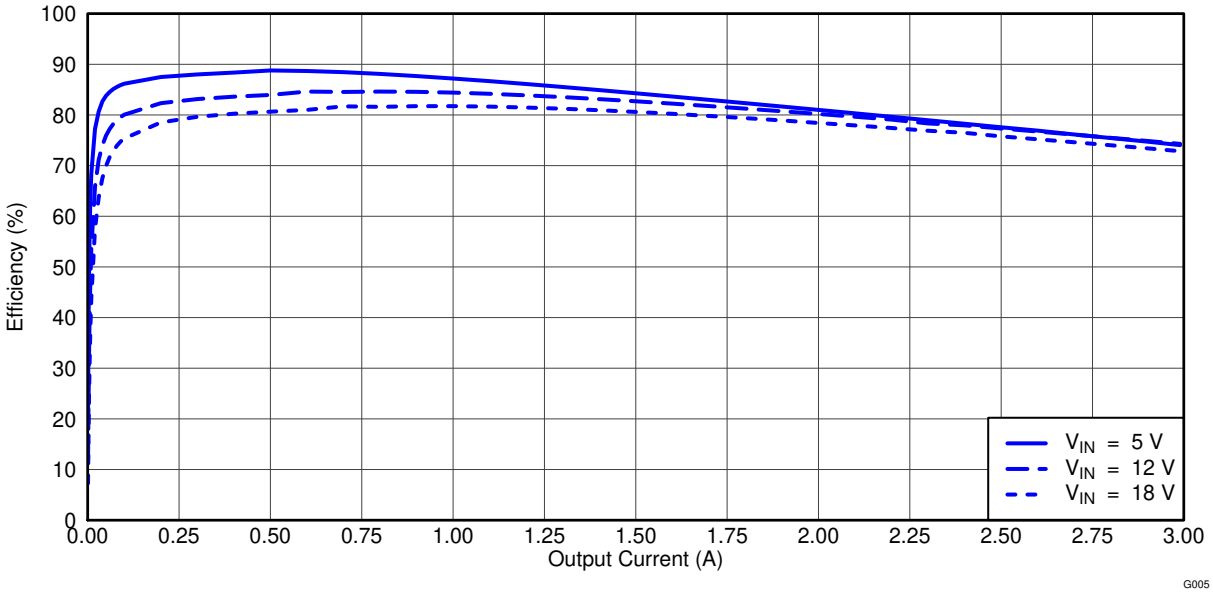

Figure 4-3. TPS542951EVM Converter 2 Efficiency

Figure 4-4 shows the light load efficiency for the converter 2 on the TPS542951EVM at an ambient temperature of 25°C.

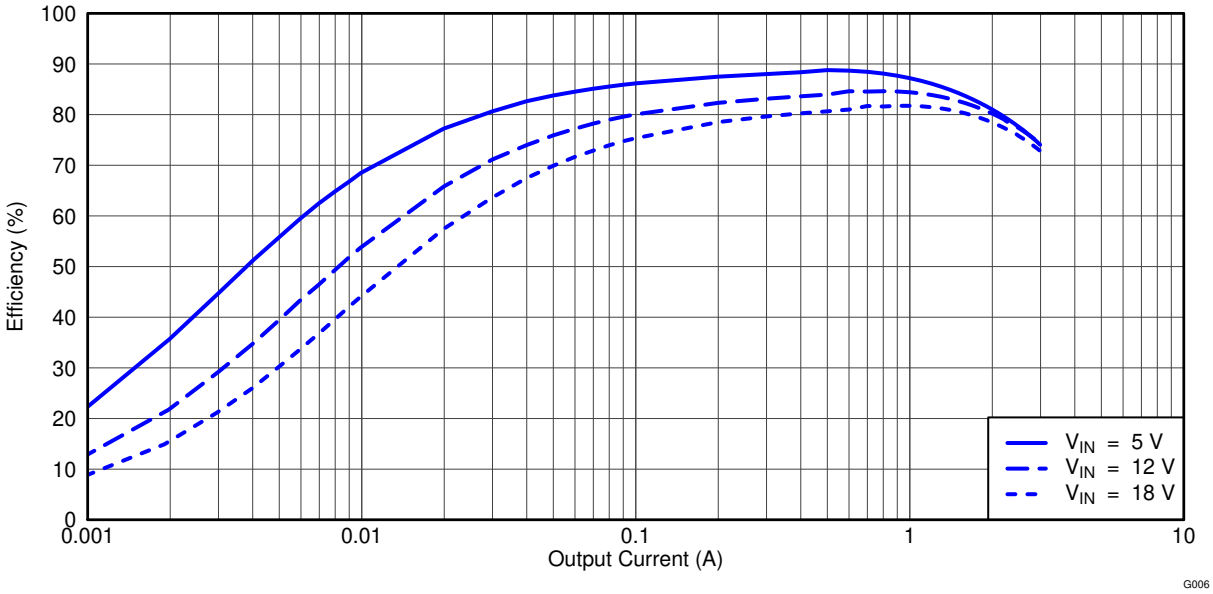

Figure 4-4. TPS542951EVM Converter 2 Light Load Efficiency

4.4 Load Regulation

4.4.1 Load Regulation of Converter 1

The load regulation for the converter 1 on the TPS542951EVM is shown in Figure 4-5. On the EVM, the load regulation of converter 1 is independent on the load of converter 2.

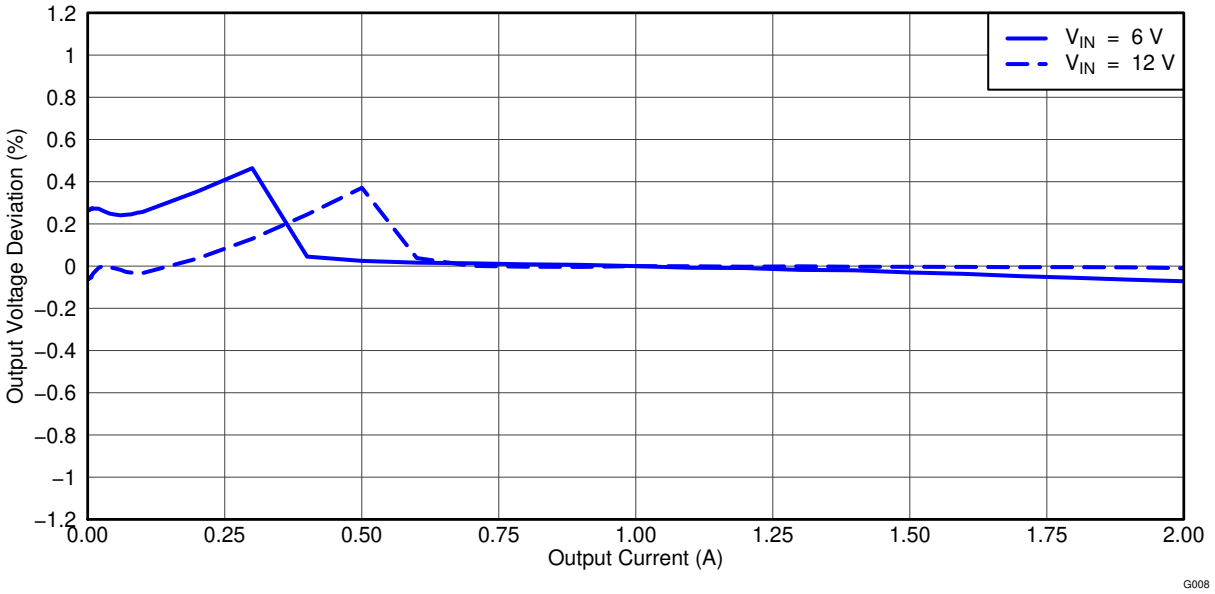

Figure 4-5. TPS542951EVM Converter 1 Load Regulation

4.4.2 Load Regulation of Converter 2

The load regulation for the converter 2 on the TPS542951EVM is shown in Figure 4-6. For 5V input voltage, the converter 2 shows on the EVM some dependency on the load of converter 1.

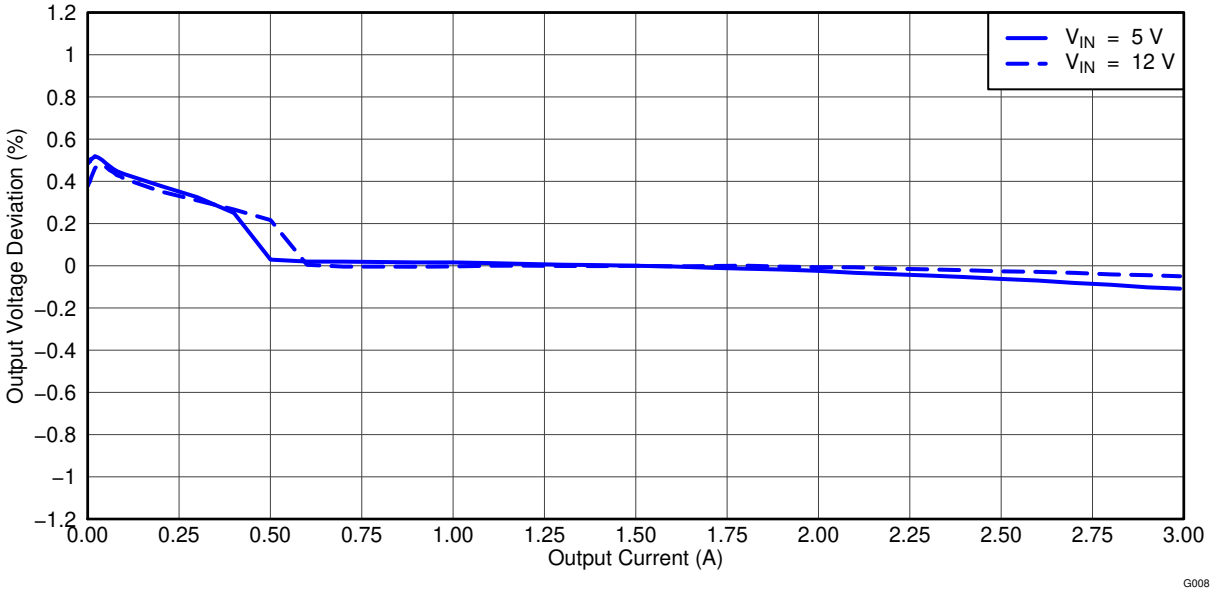

Figure 4-6. TPS542951EVM Converter 2 Load Regulation

4.5 Line Regulation

4.5.1 Line Regulation Converter 1

The line regulation of converter 1 on the TPS542951EVM is shown in Figure 4-7.

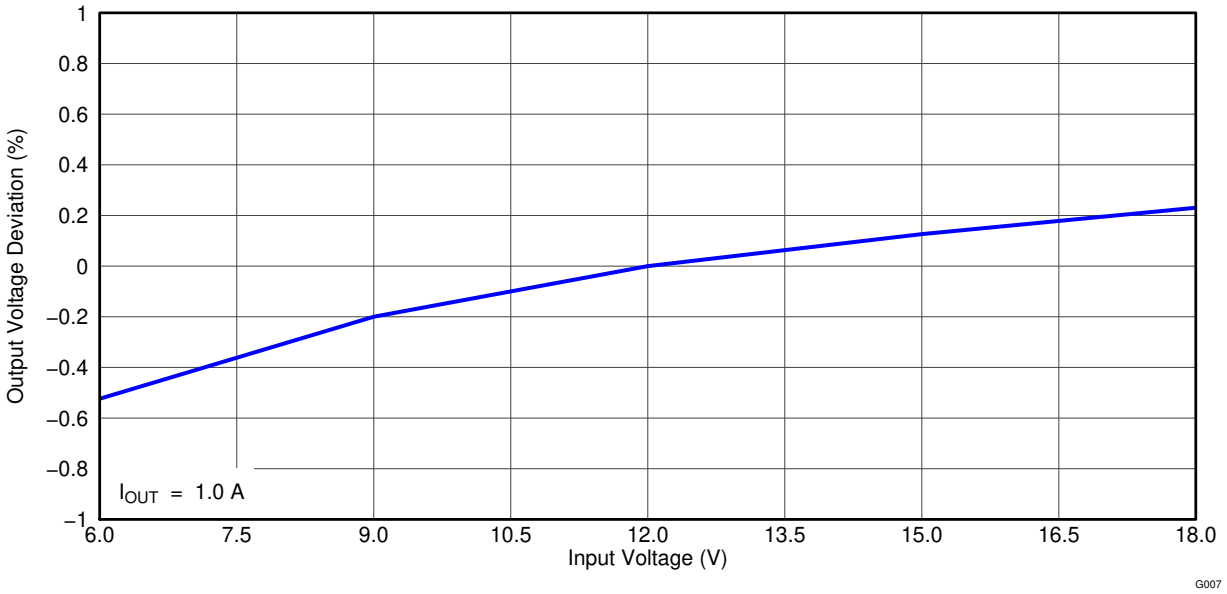

Figure 4-7. TPS542951EVM Converter 1 Line Regulation

4.5.2 Line Regulation Converter 2

The line regulation of converter 2 on the TPS542951EVM is shown in Figure 4-8.

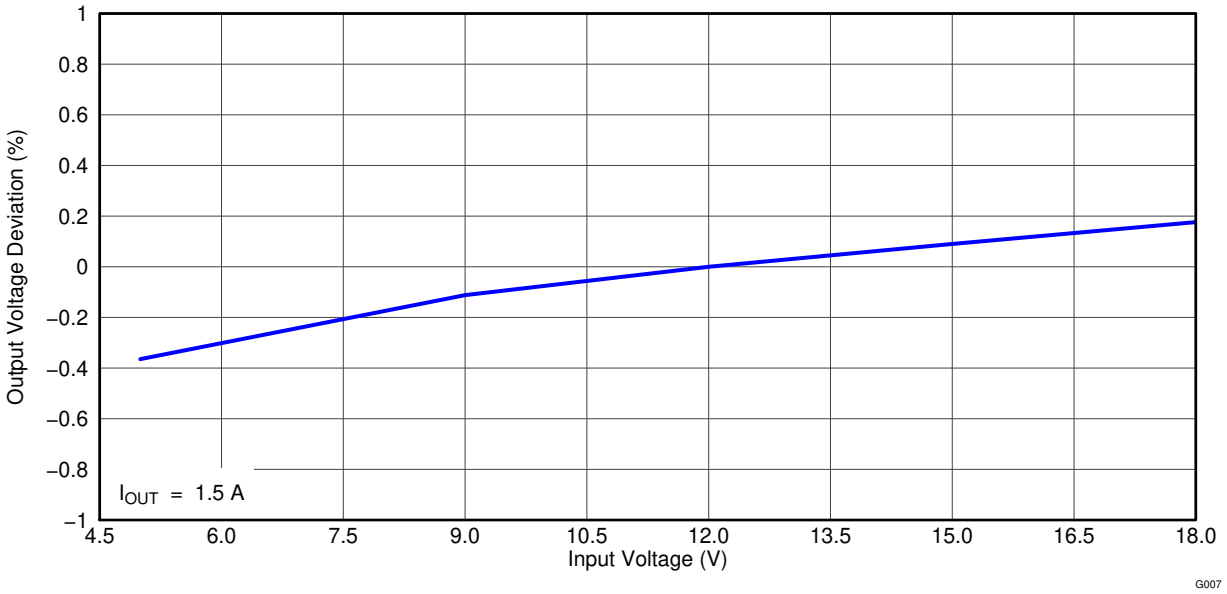

Figure 4-8. TPS542951EVM Converter 2 Line Regulation

4.6 Load Transient Response

4.6.1 Load Transient Response Converter 1

The response of converter 1 on the TPS542951EVM to a load transient is shown in Figure 4-9.

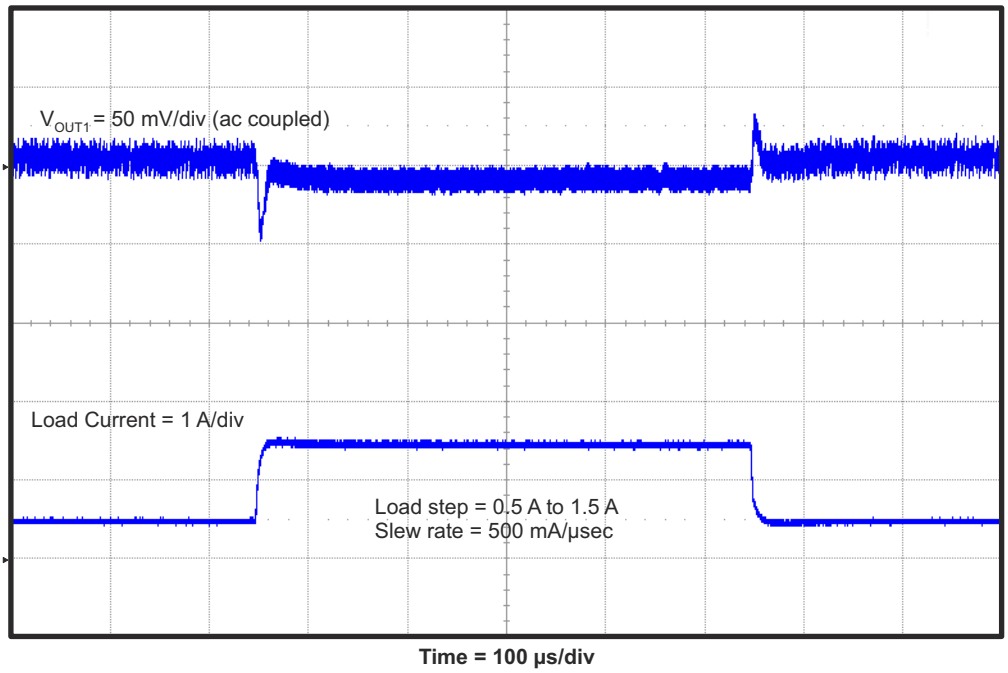

Figure 4-9. TPS542951EVM Converter 1 Load Transient Response

4.6.2 Load Transient Response Converter 2

The response of converter 2 on the TPS542951EVM to a load transient is shown in Figure 4-10.

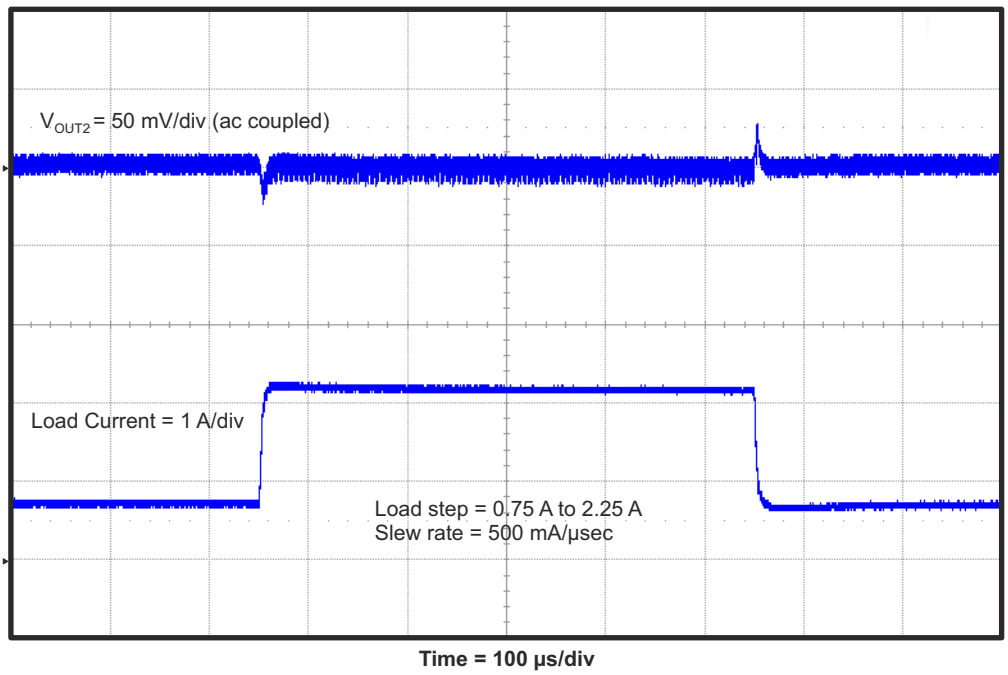

Figure 4-10. TPS542951EVM Converter 2 Load Transient Response

4.7 Output Voltage Ripple

4.7.1 Output Voltage Ripple Converter 1

The output voltage ripple of converter 1 on the TPS542951EVM is shown in Figure 4-11. The output current is the rated full load of 2 A.

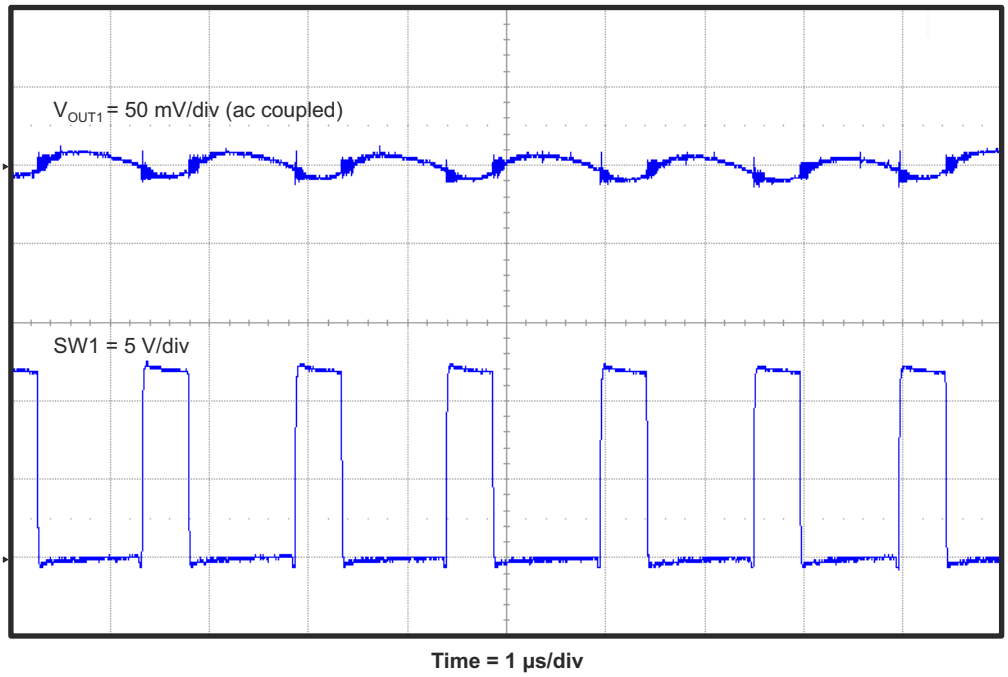

Figure 4-11. TPS542951EVM Converter 1 Output Voltage Ripple

The output voltage ripple of converter 1 on the TPS542951EVM during Eco-mode™ operation at no load is shown in Figure 4-12.

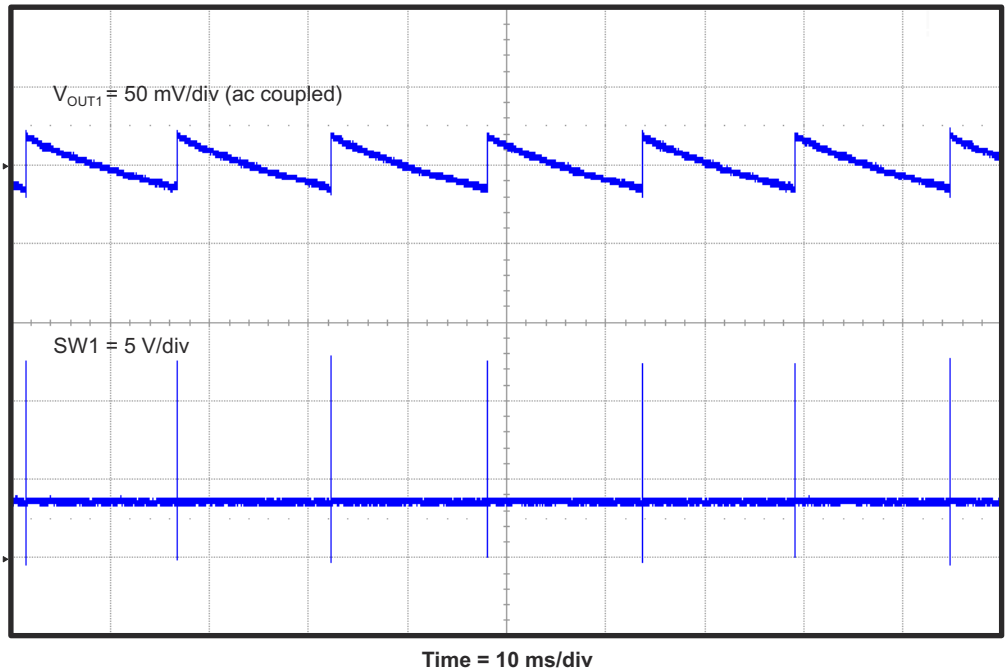

Figure 4-12. TPS542951EVM Converter 1 Eco-mode™ Output Voltage Ripple at No Load

4.7.2 Output Voltage Ripple Converter 2

The output voltage ripple of converter 2 on the TPS542951EVM is shown in Figure 4-13. The output current is the rated full load of 3 A.

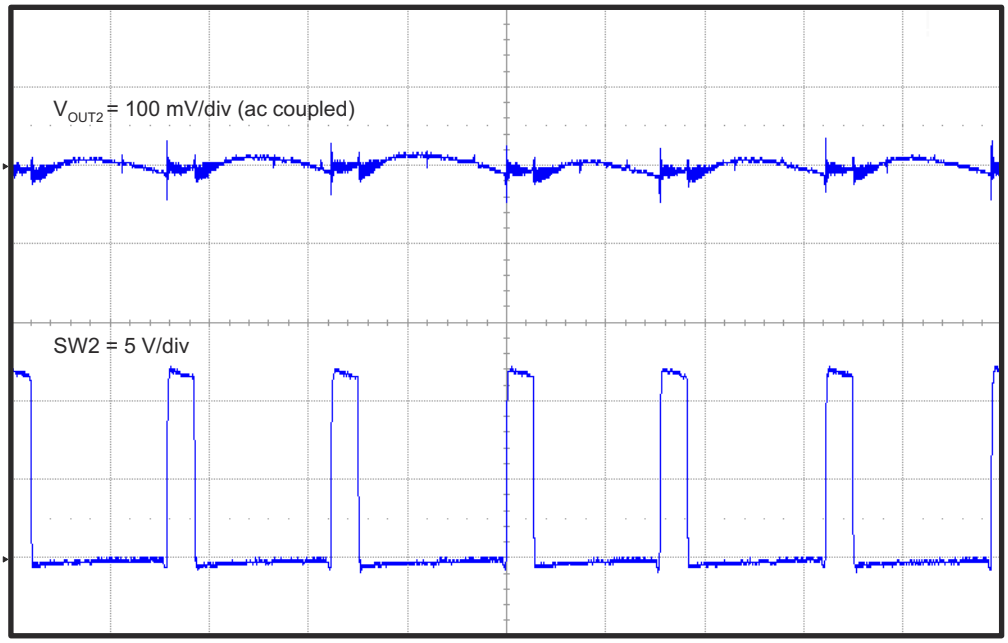

Figure 4-13. TPS542951EVM Converter 2 Output Voltage Ripple

The output voltage ripple of converter 2 on the TPS542951EVM during Eco-mode™ operation at no load is shown in Figure 4-14.

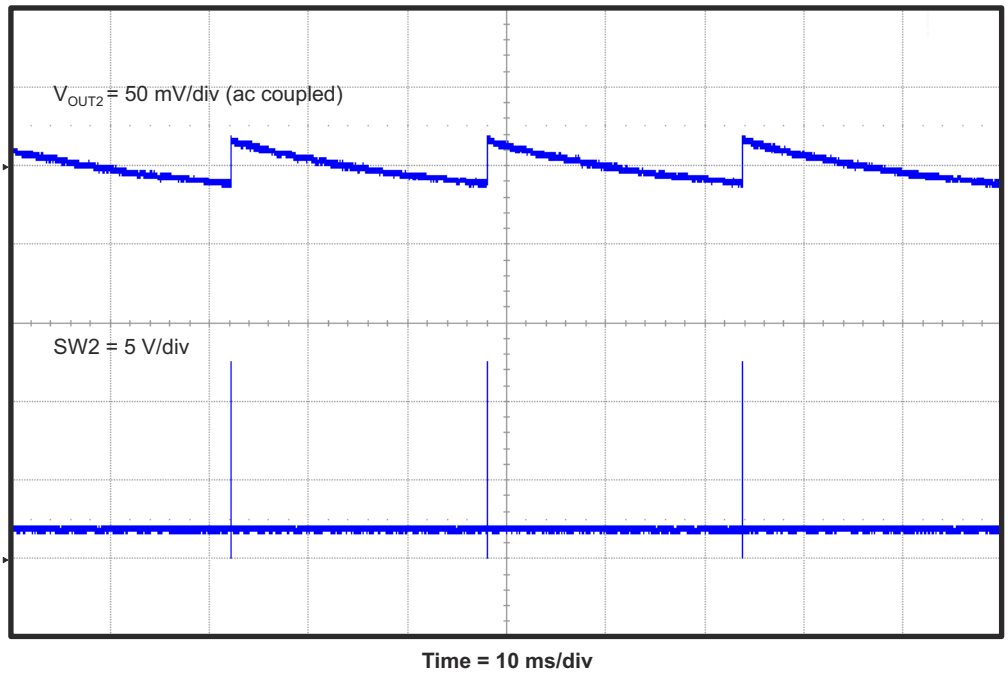

Figure 4-14. TPS542951EVM Converter 2 Eco-mode™ Output Voltage Ripple at No Load

4.8 Input Voltage Ripple

The TPS542951EVM input voltage ripple is shown in Figure 4-15. The output currents are the rated full load currents of 2 A CH1 and 3 A CH2.

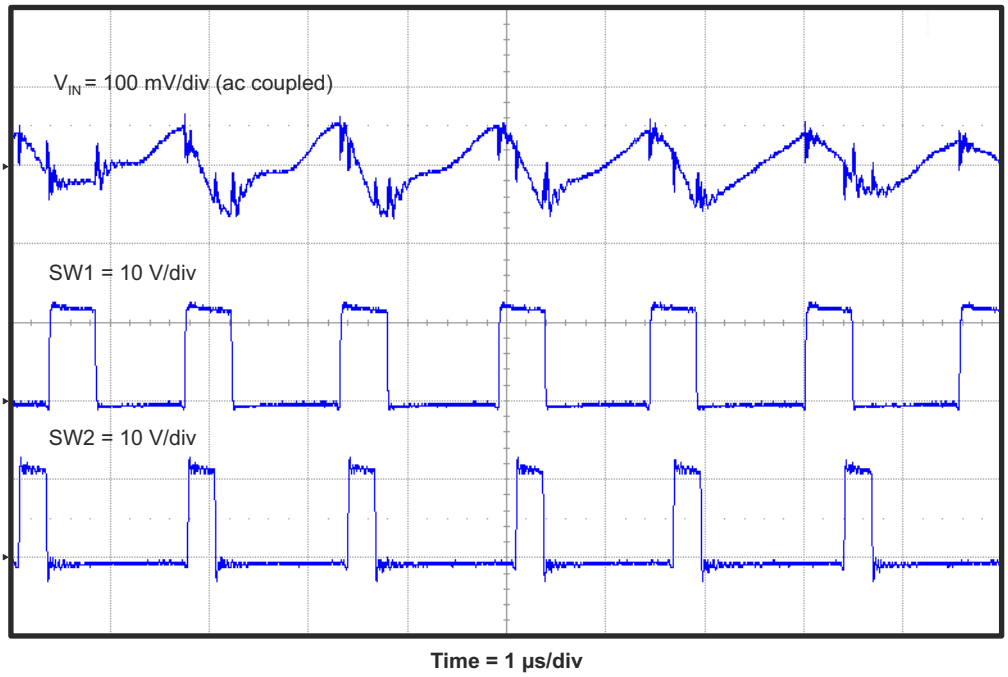

Figure 4-15. TPS542951EVM Input Voltage Ripple

4.9 Start-Up

4.9.1 Converter 1 Start-Up

The TPS542951EVM start-up waveform of converter 1 relative to V_{IN} is shown in Figure 4-16.

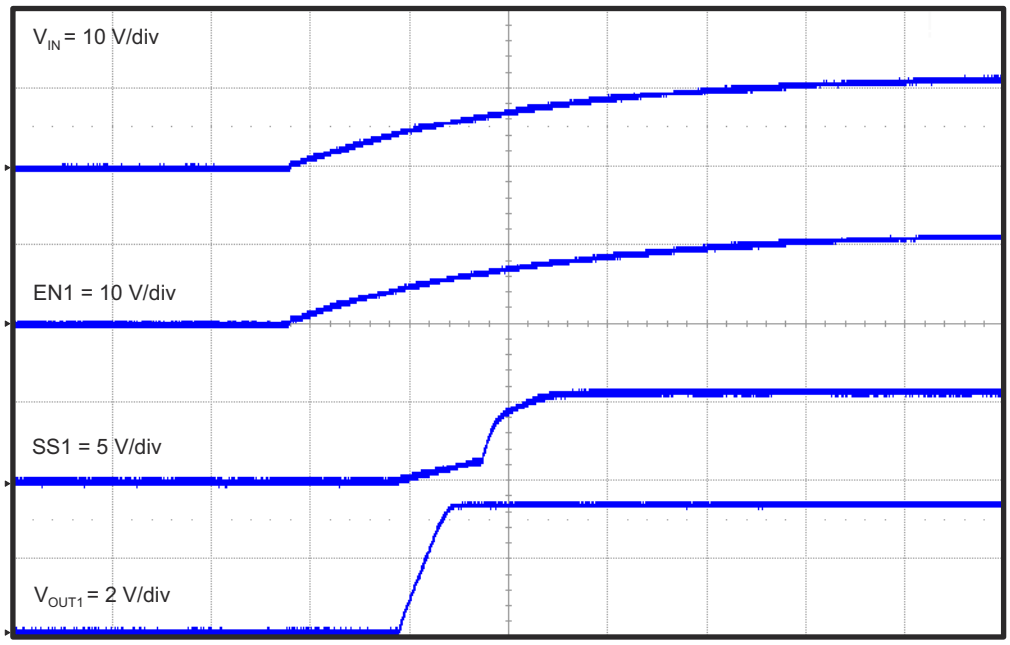

Figure 4-16. TPS542951EVM Converter 1 Start-Up Relative to V_{IN}

The TPS542951EVM start-up waveform of converter 1 relative to EN1 is shown in Figure 4-17.

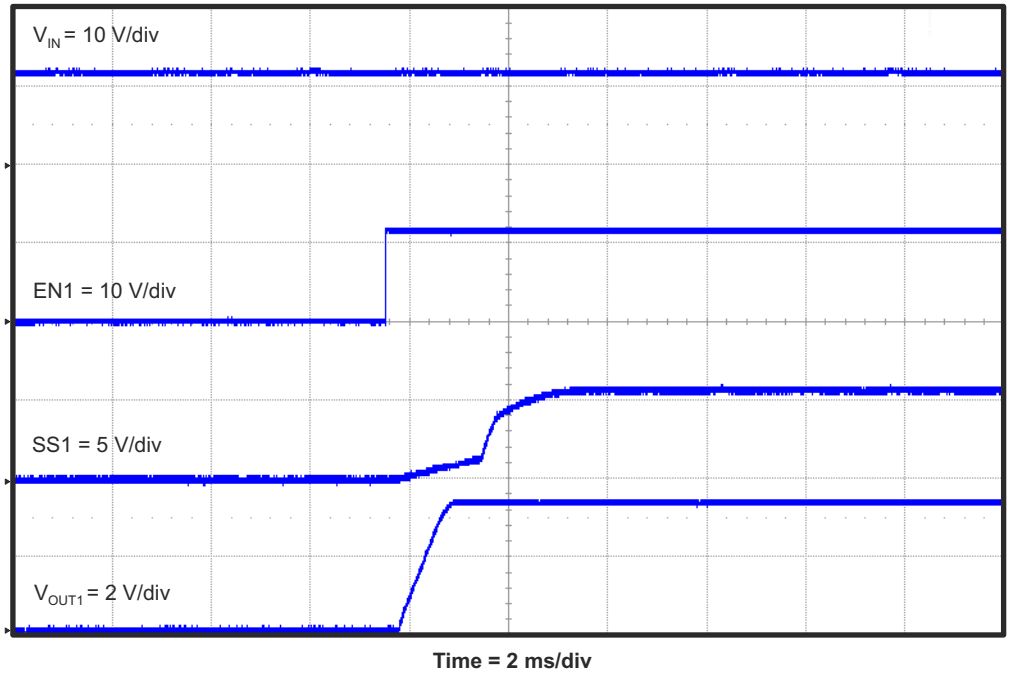

Figure 4-17. TPS542951EVM Start-Up Relative to EN1

4.9.2 Converter 2 Start-Up

The TPS542951EVM start-up waveform of converter 2 relative to V_{IN} is shown in Figure 4-18.

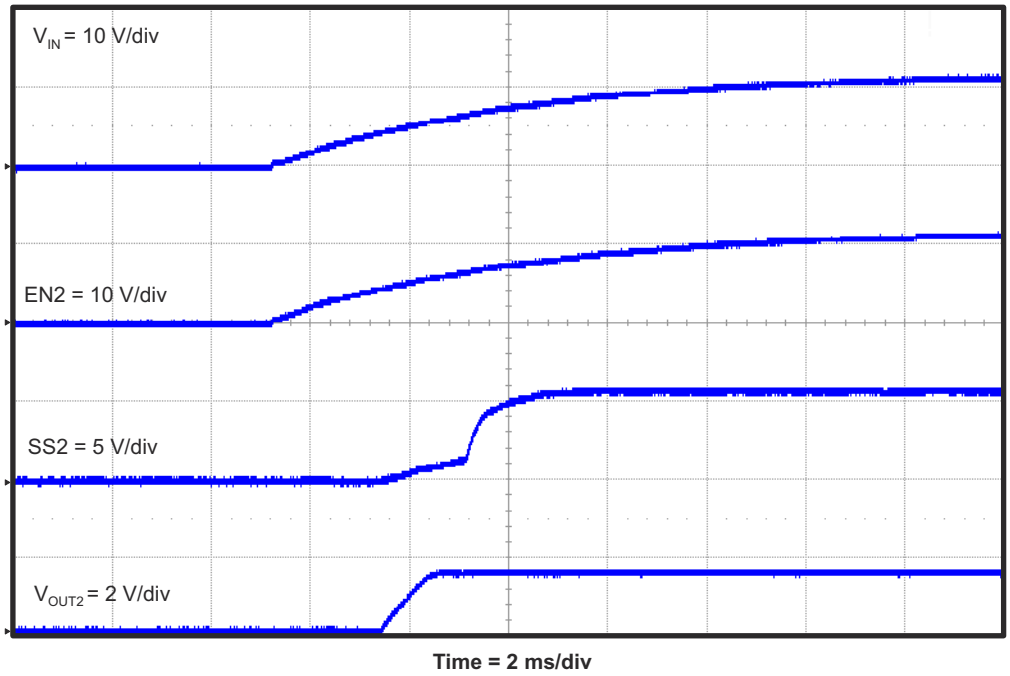

Figure 4-18. TPS542951EVM Converter 2 Start-Up Relative to V_{IN}

The TPS542951EVM start-up waveform of converter 2 relative to EN2 is shown in Figure 4-19.

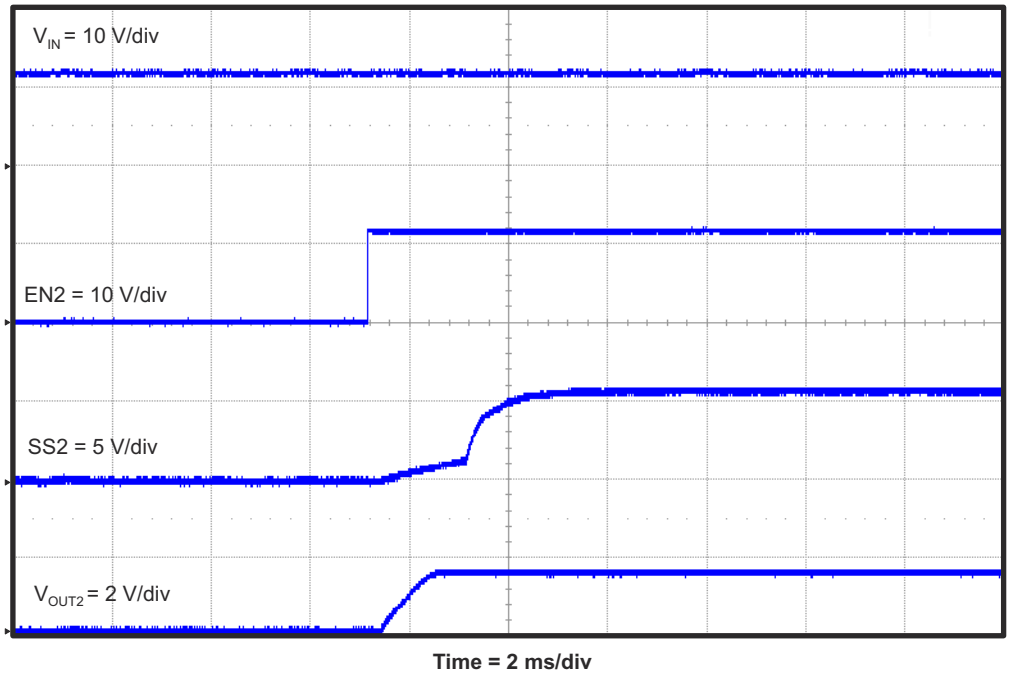

Figure 4-19. TPS542951EVM Start-Up Relative to EN2

5 Board Layout

This section provides a description of the TPS542951EVM, board layout, and layer illustrations.

5.1 Layout

The board layout for the TPS542951EVM is shown in Figure 5-1 through Figure 5-6. The top layer contains the main power traces for VIN and VOUTx. Also on the top layer are connections for the pins of the TPS542951 and a large area filled with ground. Many of the signal traces also are located on the top side. The input decoupling capacitors are located as close to the IC as possible. The input and output connectors, test points, and all of the assembled components are located on the top side. An analog ground (GND) area is provided on the top side. Analog ground (GND) and power ground (PGND) are connected at a single point on the top layer near the IC. The other layers are primarily power ground but the bottom layer has some traces to connect the test points for SSx and ENx.

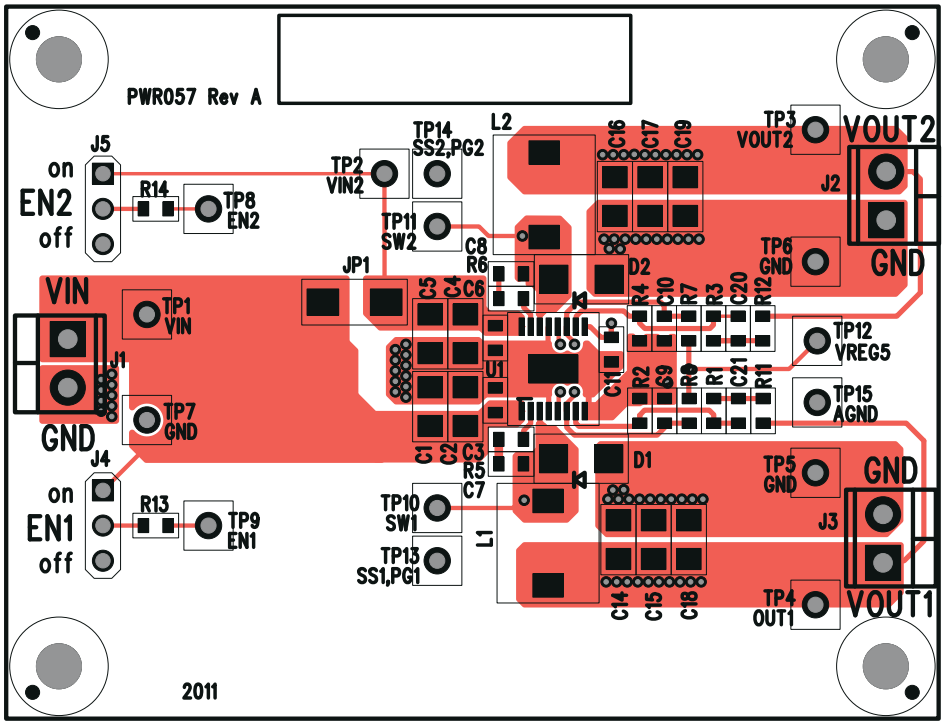

Figure 5-1. Top Assembly

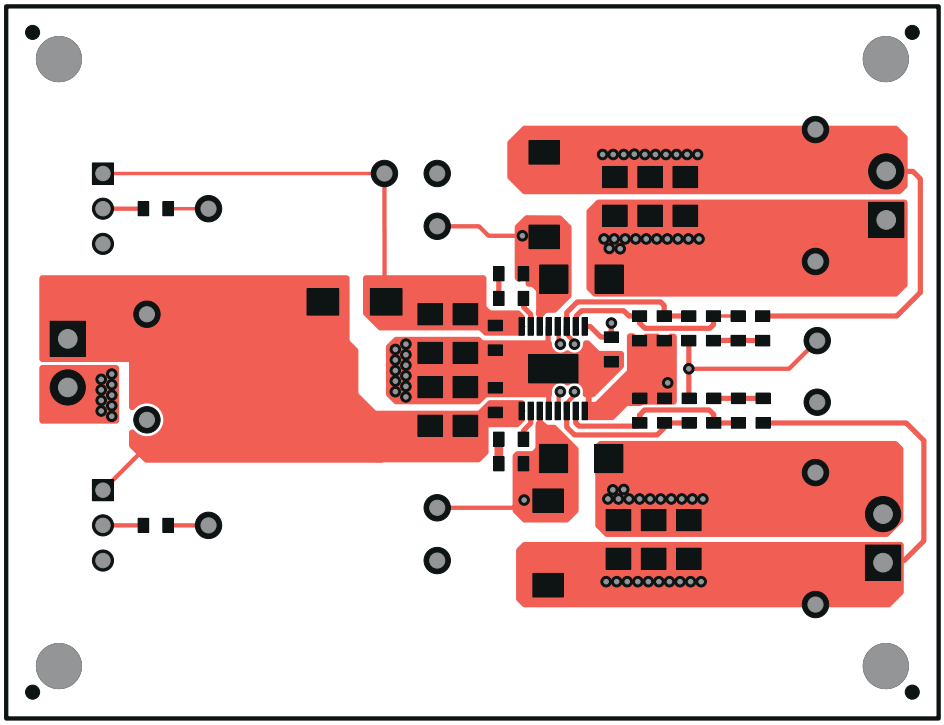

Figure 5-2. Top Layer

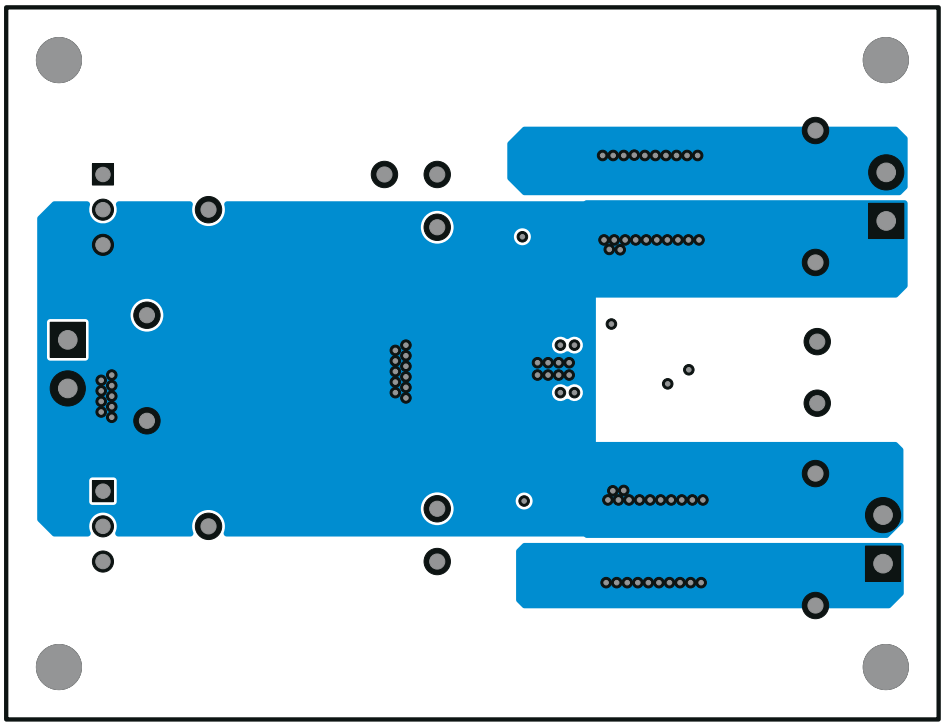

Figure 5-3. Internal 1 Layer

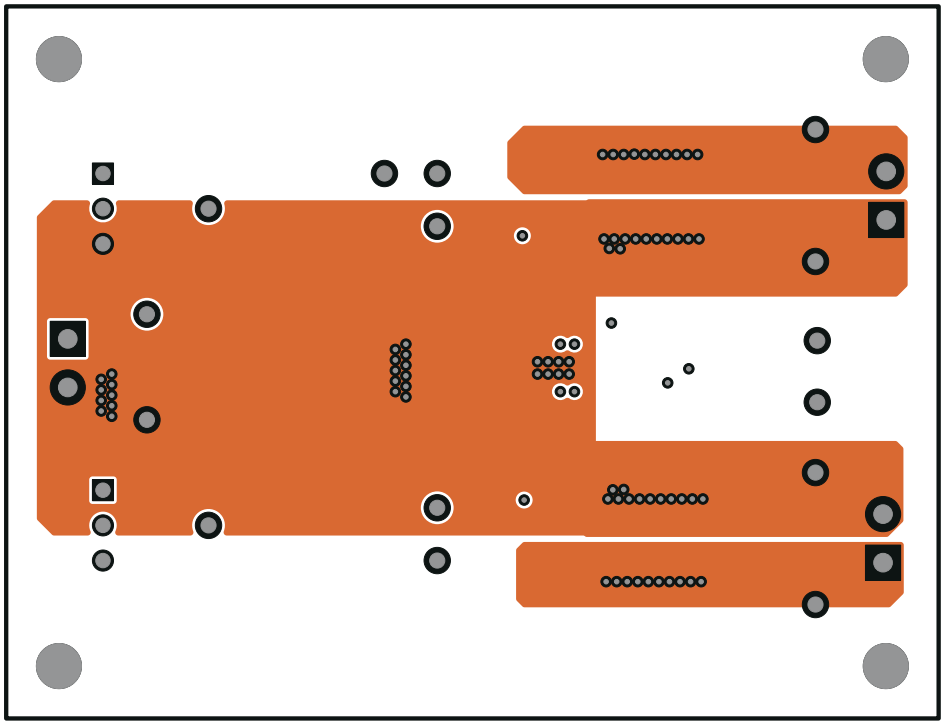

Figure 5-4. Internal 2 Layer

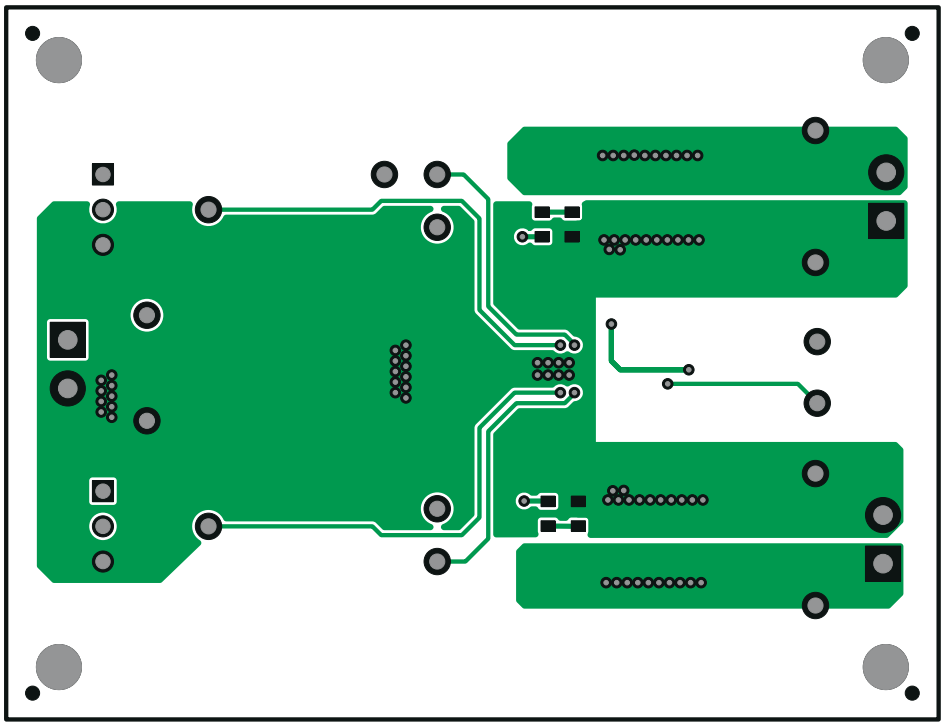

Figure 5-5. Bottom Layer

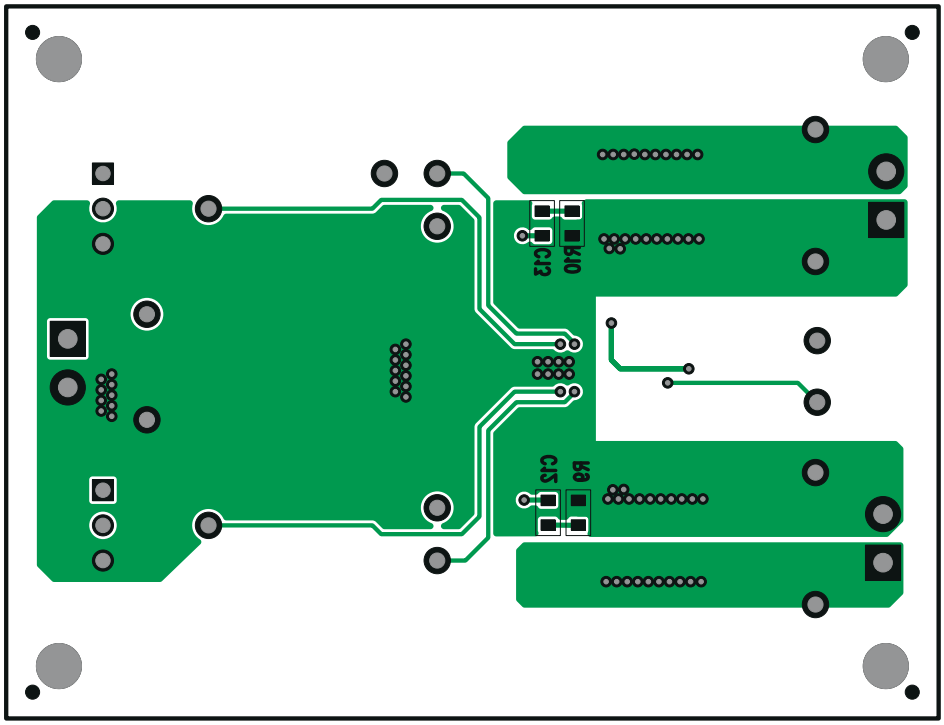

Figure 5-6. Bottom Assembly

6 Schematic, Bill of Materials, and Reference

6.1 Schematic

Figure 6-1 is the schematic for the TPS542951EVM.

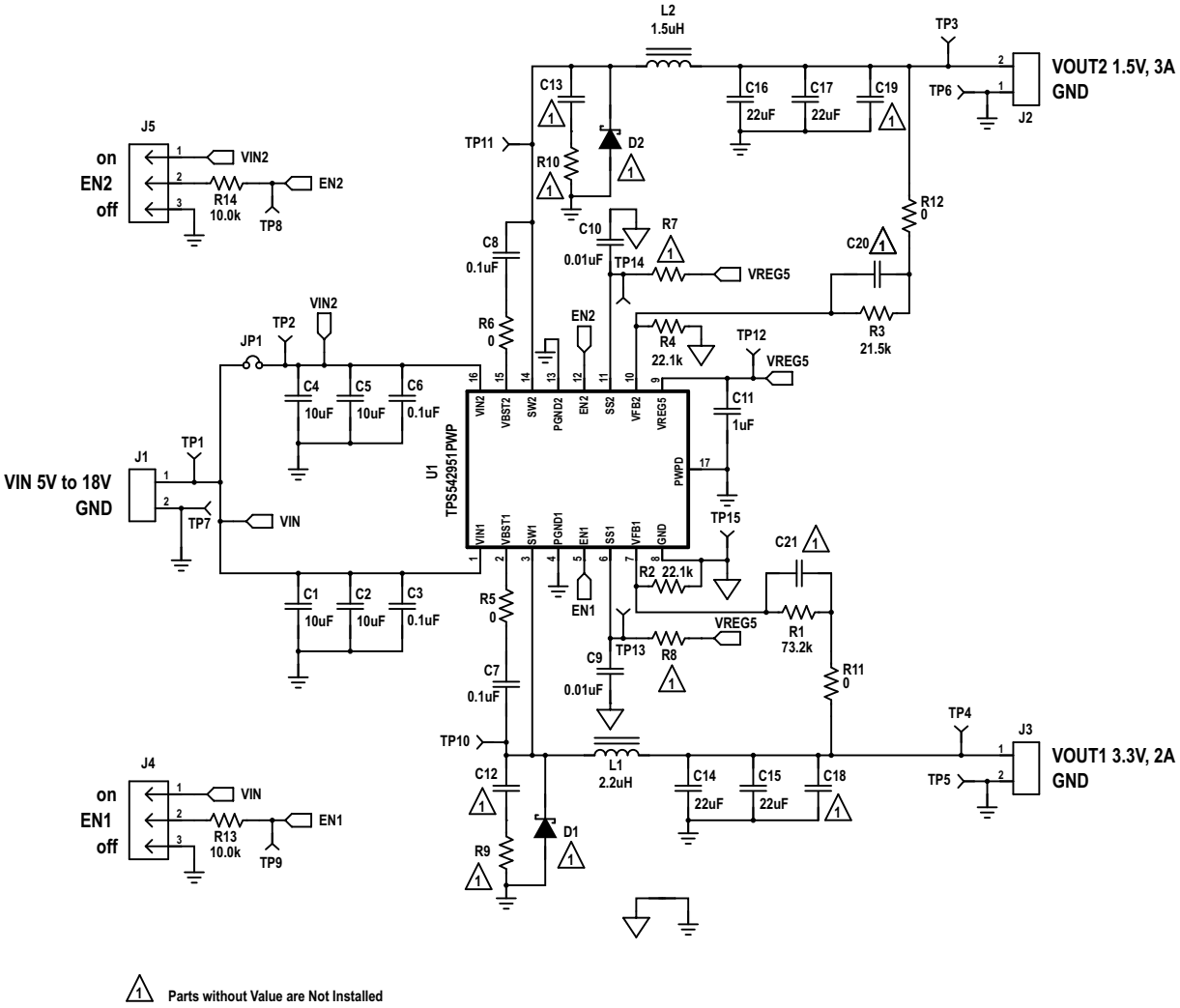

Figure 6-1. TPS542951EVM Schematic Diagram

6.2 Bill of Materials

Table 6-1. Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	Manufacturer
1	C11	1 µF	Capacitor, ceramic, 16 V, X7R, 10%	0603	GRM188R71C105KA12	Murata
4	C1-2 C4-5	10 µF	Capacitor, ceramic, 25 V, X7R, 10%	1206	GRM31CR71E106KA12	Murata
0	C12-13	open	Capacitor, ceramic, 50 V, X7R, 10%	0603	GRM188R71H104KA93	Murata
4	C14-17	22 µF	Capacitor, ceramic, 6.3 V, X7R, 10%	1206	GRM31CR70J226KE19	Murata
0	C18-19	open	Capacitor, ceramic, 6.3 V, X7R, 10%	1206		
0	C20-21	open	Capacitor, ceramic, 50 V, X7R, 10%	0603	Std	Std
4	C3 C6-8	0.1 µF	Capacitor, ceramic, 50 V, X7R, 10%	00603	GRM188R71H104KA93	Murata
2	C9-10	0.01 µF	Capacitor, ceramic, 50 V, X7R, 10%	0603	Std	Std
0	D1-2	open	Diode, Schottky	SMA	STD	STD
1	L1	2.2 µH	Inductor, power line, magnetic shielded, ±30%, 4.3 A	6.9 × 7.2 mm	SPM6530-2R2M	TDK
1	L2	1.5 µH	Inductor, power line, magnetic shielded, ±30%, 4.1 A	6.9 × 7.2 mm	SPM6530-1R5M	TDK
1	R1	73.2 kΩ	Resistor, chip, 1/16W, 1%	0603	STD	STD
2	R11-12	0 Ω	Resistor, chip, 1/16W, 5%	0603	STD	STD
2	R13-14	10.0 kΩ	Resistor, chip, 1/16W, 1%	0603	STD	STD
2	R2 R4	22.1 kΩ	Resistor, chip, 1/16W, 1%	0603	STD	STD
1	R3	21.5 kΩ	Resistor, chip, 1/16W, 1%	0603	STD	STD
2	R5-6	0 Ω	Resistor, chip, 1/16W, 1%	0603	STD	STD
0	R7-8	open	Resistor, chip, 1/16W, 1%	0603	STD	STD
0	R9-10	open	Resistor, chip, 1/16W, 1%	0603	STD	STD
1	U1	TPS542951PWP	IC, 2A/3A, dual output fully synchronous buck converter with integrated FET	TSSOP	TPS542951PWP	TI

C14-C19 must be replaced with capacitors which have a higher voltage rating when the output voltage is set above 4V.

6.3 Reference

Texas Instruments, *TPS542951, 3-A Dual Channel Synchronous Step-Down Switcher With Integrated FETs Data Sheet*

7 Revision History

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

Changes from Revision * (August 2012) to Revision A (October 2021)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document.	3
• Updated the user's guide title.	3

STANDARD TERMS FOR EVALUATION MODULES

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

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

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

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

NOTE:

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

3 *Regulatory Notices:*

3.1 *United States*

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

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

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

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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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.

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