Texas Instruments

TPS54314 3-A Internally Compensated SWIFT™ Regulator EVM

User's Guide

July 2003

EVM IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation kit being sold by TI is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not considered by TI to be fit for commercial use. As such, the goods being provided may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety measures typically found in the end product incorporating the goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet the technical requirements of the directive.

Should this evaluation kit not meet the specifications indicated in the EVM User's Guide, the kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Please be aware that the products received may not be regulatory compliant or agency certified (FCC, UL, CE, etc.). Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive**.

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein**.

Please read the EVM User's Guide and, specifically, the EVM Warnings and Restrictions notice in the EVM User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact the TI application engineer.

Persons handling the product must have electronics training and observe good laboratory practice standards.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 3 V to 6 V

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 125°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

Preface

Read This First

About This Manual

This users guide describes the characteristics, operation, and use of the TPS54314, 3-A, 1.8-V, internally compensated, SWIFT™ regulator evaluation module (EVM). This user's guide includes a schematic diagram and bill of materials.

How to Use This Manual

This document contains the following chapters:

- Chapter 1—Introduction
- Chapter 2—Test Setup and Results
- Chapter 3—Board Layout
- Chapter 4—Schematic and Bill of Materials

Related Documentation From Texas Instruments

- *SWIFT™ Designer* software tool
- Application report SLVA111—*Designing With the TPS54311 Through TPS54316 Synchronous Buck Regulators*

FCC Warning

This equipment is intended for use in a laboratory test environment only. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to subpart J of part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

Trademarks

SWIFT and PowerPAD are trademarks of Texas Instruments.

Contents

1 Introduction 1-1
1.1 Background 1-2
1.2 Performance Specification Summary 1-2
1.3 Modifications 1-3
1.3.1 General 1-3
1.3.2 Switching Frequency 1-3
1.3.3 Output Voltage 1-3
1.3.4 Slow Start 1-4

2 Test Setup and Results 2-1
2.1 Input/Output Connections 2-2
2.2 Efficiency 2-2
2.3 Thermal Performance 2-3
2.4 Output Voltage Regulation 2-4
2.5 Load Transients 2-5
2.6 Loop Characteristics 2-5
2.7 Output Ripple Voltage 2-6
2.8 Input Ripple Voltage 2-6
2.9 Start-Up 2-7

3 Board Layout 3-1
3.1 Layout 3-2

4 Schematic and Bill of Materials 4-1
4.1 Schematic 4-2
4.2 Bill of Materials 4-3

Figures

1–1 Frequency Trimming Resistor Selection Graph 1-3
2–1 Connection Diagram 2-2
2–2 Measured Efficiency 2-3
2–3 Measured Board Losses 2-3
2–4 Measured Junction Temperature at 25°C Ambient 2-4
2–5 Measured Load Regulation 2-4
2–6 Measured Load Transient Response 2-5
2–7 Measured Loop Gain and Phase 2-5
2–8 Measured Output Ripple Voltage 2-6
2–9 Measured Input Ripple Voltage 2-6
2–10 Measured Start-Up Waveforms 2-7
3–1 Top Side Assembly 3-2
3–2 Top Side Layout 3-3
3–3 Bottom Side Layout 3-4
4–1 TPS54314 EVM Schematic 4-2

Tables

1–1 Performance Specification Summary 1-2
1–2 Device Modification 1-4
4–1 TPS54314EVM Bill of Materials 4-3

Chapter 1

Introduction

This chapter contains background information for the TPS54314 and support documentation for the TPS54314 evaluation module. The EVM performance specifications are also given.

Topic **Page**

1.1	Background	1-2
1.2	Performance Specification Summary	1-2
1.3	Modifications	1-3

1.1 Background

The TPS54314EVM evaluation module uses the TPS54314 synchronous buck regulator to provide a 1.8-V output over an input range of 3 V to 6 V and over a load range of 0 A to 3 A. The electrical components of the TPS54314 circuit consume less than 0.6 square inches of board space. Additional pads are provided to support multiple input and output capacitors. A jumper is provided to allow the switching frequency to be easily changed from 350 kHz to 550 kHz.

The TPS54314 has two key features that reduce the number of additional components compared to traditional synchronous buck controllers. The first feature is that the MOSFETs are incorporated inside the TPS54314 package. This eliminates the need for external MOSFETs and their associated drivers. The second feature is that the compensation components that stabilize the feedback loop are also incorporated inside the TPS54314 package.

Because the internal compensation of the TPS54314 is fixed, loop stability is assured by the proper selection of an output inductor and output capacitor. For guidelines on selecting an output inductor and output capacitor for a specific application, refer to Texas Instruments application report, literature number SLVA111, *Designing With The TPS54311 Through TPS54316 Synchronous Buck Regulators.*

1.2 Performance Specification Summary

Table 1–1 provides a summary of the TPS54314EVM performance specifications. All specifications are given for an ambient temperature of 25°C, unless otherwise noted.

Table 1–1. Performance Specification Summary

Specification	Test Conditions	Min	Typ	Max	Units
Input voltage range		3	5	6	V
Output voltage set point			1.8		V
Output current range		0		3	A
Load regulation	V_I = 5 V	–7		7	mV
Load transient response	I_O = 0 A to 3 A		–60		mV_{PK}
			30		µs
	I_O = 3 A to 0 A		70		mV_{PK}
			30		µs
Loop bandwidth	V_I = 5 V, I_O = 3 A		70		kHz
Phase margin	V_I = 5 V, I_O = 3 A		49		°
Input ripple voltage			150		mV_{PP}
Output ripple voltage			15	30	mV_{PP}
Output rise time		2.6	3.6	4.1	ms
Operating frequency		640	700	760	kHz
Efficiency	V_I = 5 V, I_O = 1 A		91.5%		

1.3 Modifications

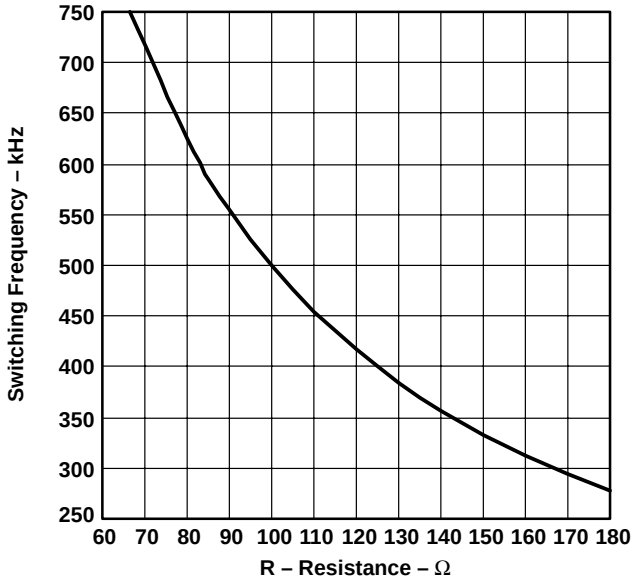
1.3.1 General

The TPS54314EVM is designed to demonstrate the small amount of board space taken up by the TPS54314 electrical components. In addition, the EVM can be used to evaluate different output filters by substituting an alternative inductor for L1, or by using the optional pads for capacitors C2 and C10 (see Figure 4–1). Because the feedback compensation is fixed by the internal circuitry of the TPS54314, proper selection of the output inductor and output capacitor ensures stability. The *SWIFT Designer* software tool or Texas Instruments application note SLVA111 can be used to assist in the selection of an output filter. Both SWIFT Designer and SLVA111 are available for download at the Texas Instruments web site.

1.3.2 Switching Frequency

The TPS54314 is configured to switch at a frequency of 700 kHz. Alternatively the EVM can be easily configured to switch at either 350 kHz or 550 kHz by removing the frequency trimming resistor R3 and placing the shunt on jumper JP1 in the proper location. Also, by changing the value of RT (R3), the switching frequency can be trimmed to any value between 280 kHz and 700 kHz. A plot of the value of RT versus the switching frequency is given in Figure 1–1.

Figure 1–1. Frequency Trimming Resistor Selection Graph



1.3.3 Output Voltage

The EVM can be modified for different preset output voltages by using other devices in the TPS5431x family. The only U1 component needs to be changed. Table 1–2 lists the devices required for U1 for different output voltage options.

Table 1–2. Device Modification

Output Voltage (V)	Device (U1)
0.9	TPS54311
1.2	TPS54312
1.5	TPS54313
1.8	TPS54314
2.5	TPS54315
3.3	TPS54316

1.3.4 Slow Start

The slow start time of the TPS54314EVM can be modified by changing the value of C1. Equation 1 can be used to calculate the value of C1 for a specific slow start time. With C1 left open, the slow start time is typically 3.6 ms. The slow start time can not be made faster than 3.6 ms.

$$C_1 = \frac{T_{SS} \times 5\ \mu A}{0.891\ V} \quad (1)$$

Chapter 2

Test Setup and Results

This chapter describes how to properly connect, setup, and use the TPS54314EVM. It also presents the test results and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up

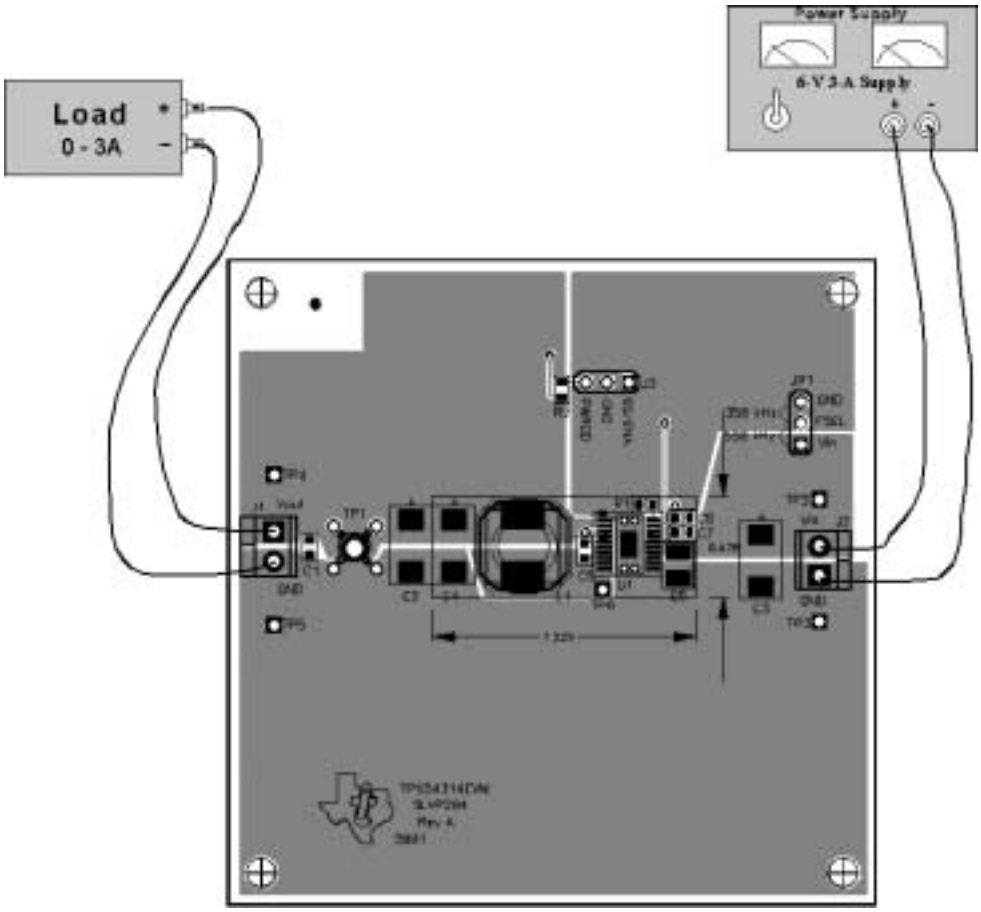
Topic **Page**

2.1	Input/Output Connections	2-2
2.2	Efficiency	2-2
2.3	Thermal Performance	2-3
2.4	Output Voltage Regulation	2-4
2.5	Load Transients	2-5
2.6	Loop Characteristics	2-5
2.7	Output Ripple Voltage	2-6
2.8	Input Ripple Voltage	2-6
2.9	Start-Up	2-7

2.1 Input/Output Connections

The TPS54314EVM has the following four input/output connections: J1 (V_I and GND) and J2 (V_O and GND). A diagram showing the connection points is shown in Figure 2–1. Connect a power supply capable of supplying 3 A to J1 through a pair of 20 AWG wires. Connect the load to J2 through a pair of 20 AWG wires. Minimize wire lengths to reduce losses in the wires. Test point TP8 provides easy connection for an oscilloscope voltage probe to monitor the output voltage.

Figure 2–1. Connection Diagram



2.2 Efficiency

The TPS54314EVM efficiency peaks at around 1 A of load current, with a 5-V input source. At full load this drops to around 85%. Figure 2–2 shows the typical efficiency for both a 5-V input and a 3.3-V input and an ambient temperature of 25°C. The efficiency is lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the MOSFETs. The efficiency is also slightly higher at lower switching frequencies due to the gate and switching losses in the MOSFETs. The efficiency is slightly higher with a 5-V input because the higher input voltage provides more drive voltage for the power MOSFETs, which leads to a lower drain-to-source resistance. The total board losses are shown in Figure 2–3.

Figure 2–2. Measured Efficiency

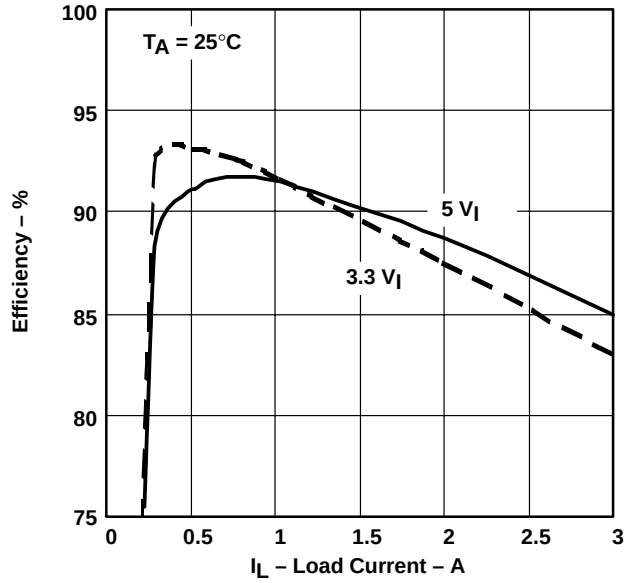
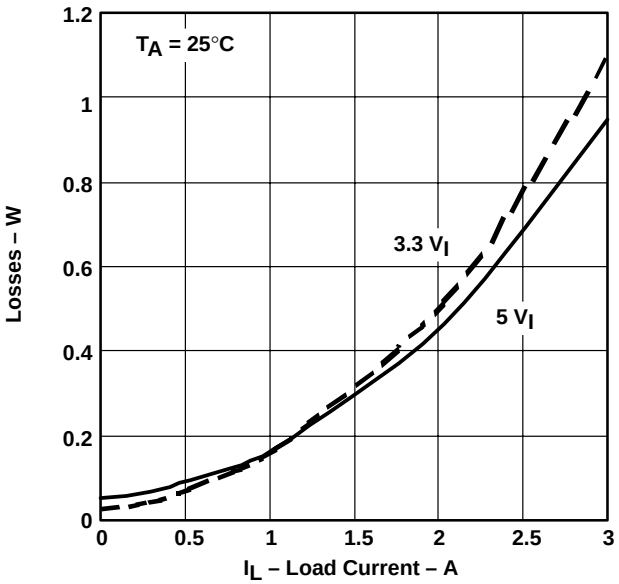


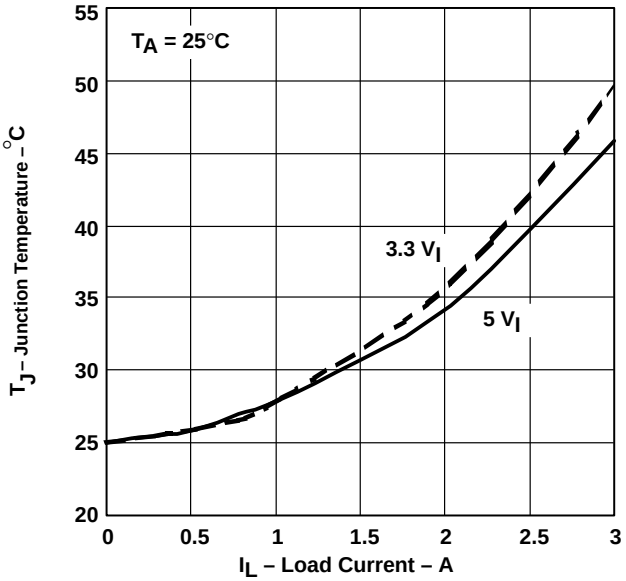
Figure 2–3. Measured Board Losses



2.3 Thermal Performance

The junction temperature is plotted versus the load current with a 25°C ambient temperature in Figure 2–4. The low junction-to-case thermal resistance of the PWP package, along with a good board layout, helps to keep the junction temperature low at high output currents. With a 5-V input source and a 3-A load, the junction temperature is approximately 45°C.

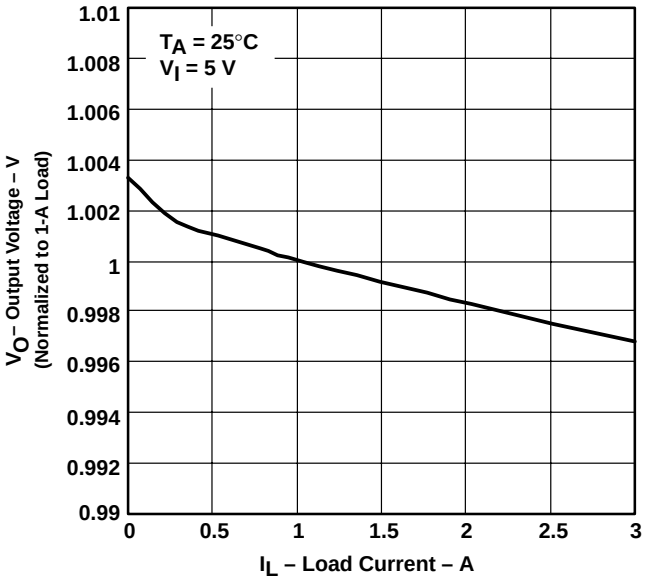
Figure 2–4. Measured Junction Temperature at 25°C Ambient



2.4 Output Voltage Regulation

The output voltage load regulation with a 5-V input and a 25°C ambient temperature is shown in Figure 2–5. Over the load range of 0 A to 3 A, the output voltage varies less than 0.35%.

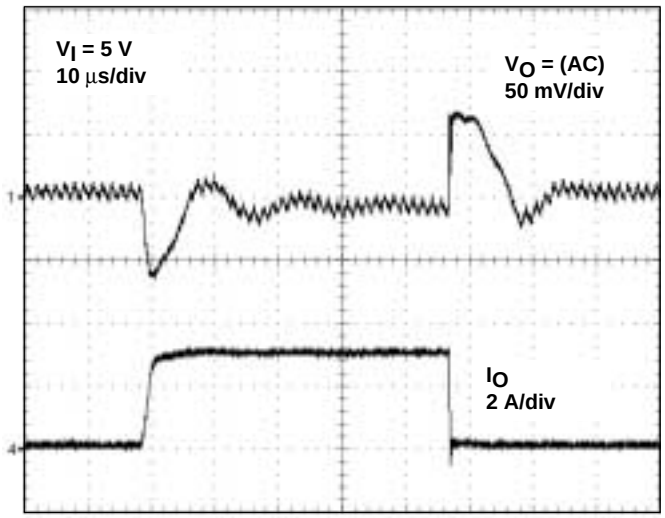
Figure 2–5. Measured Load Regulation



2.5 Load Transients

The TPS54314EVM response to load transients is shown in Figure 2–6. The load transient in Figure 2–6 transitions between 0 A and 3 A. The output voltage deviates approximately –60 mV (–3.3%) and 70 mV (3.9%) from its average value as a result of these transients. In Figure 2–6, the output voltage returns to a ±2% regulation band within 30 μs.

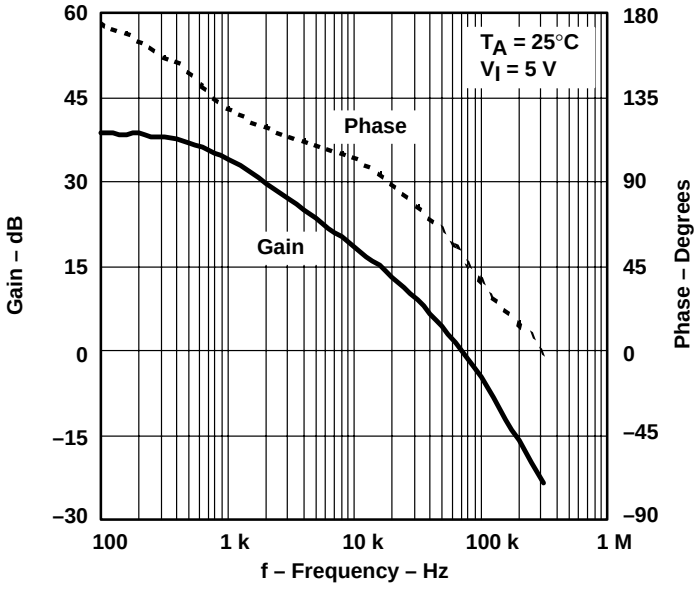
Figure 2–6. Measured Load Transient Response



2.6 Loop Characteristics

The loop gain and phase for a 5-V input and a 3-A load is shown in Figure 2–7. The loop crossover frequency is approximately 70 kHz, and the phase margin is approximately 49°.

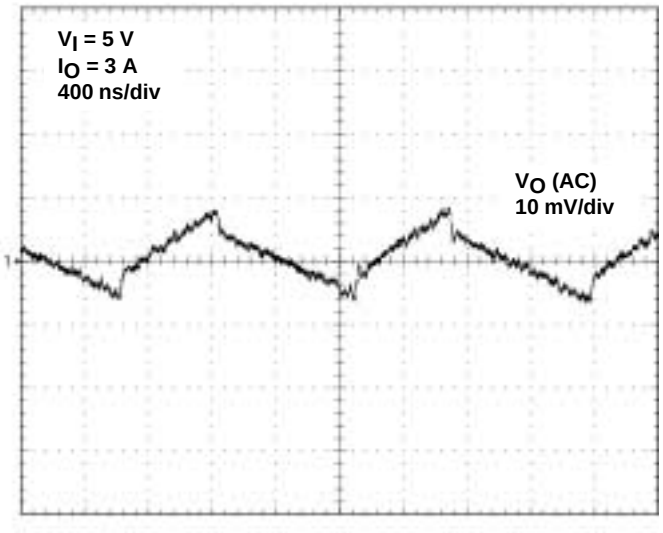
Figure 2–7. Measured Loop Gain and Phase



2.7 Output Ripple Voltage

The output ripple voltage is plotted in Figure 2–8 with an input voltage of 5 V and a load current of 3 A. The TPS54314EVM has a typical output voltage ripple of less than 20 mV_{pp}. If the switching frequency is reduced, the output ripple voltage is higher.

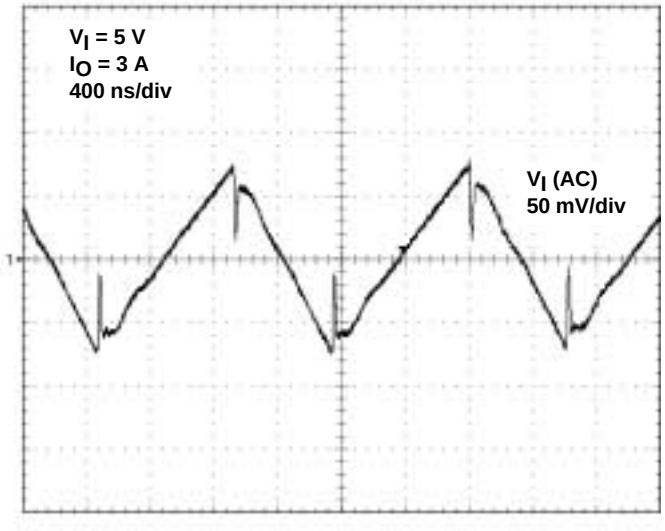
Figure 2–8. Measured Output Ripple Voltage



2.8 Input Ripple Voltage

The input ripple voltage for a 3-A load is shown in Figure 2–9. With an input voltage of 5 V, the input ripple is approximately 150 mV_{pp}. The input ripple voltage can be made lower by adding capacitance to the input.

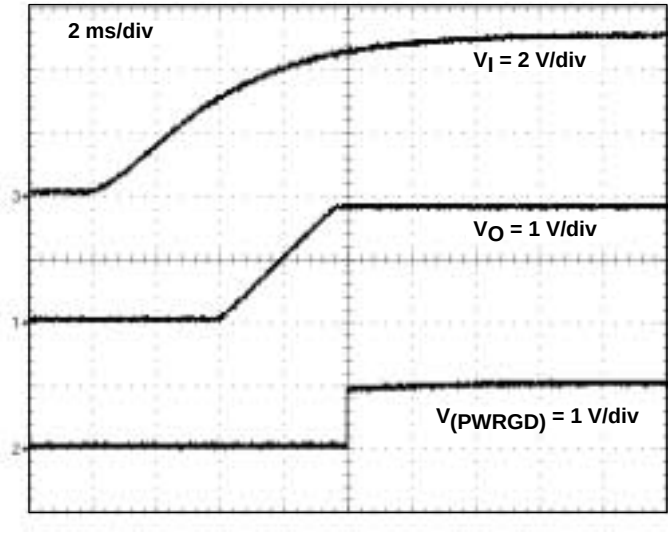
Figure 2–9. Measured Input Ripple Voltage



2.9 Start-Up

The start-up voltage waveform of the TPS54314EVM, with C1 left open, is shown in Figure 2–10. In Figure 2–10, the input voltage is displayed on channel 3, the output voltage is displayed on channel 1, and the power good signal is displayed on channel 2. Once the input voltage rises above the 2.9-V start-up threshold, the output voltage begins to rise linearly to 1.8 V in 3.6 ms. Once the output voltage has reached its final value, the open-drain power good signal rises to a high state. The start-up time can be extended by using an external slow start capacitor, C1. To program a specific slow start time, see section *1.3.4 Slow Start.* The shorting jumper on J2 should not be used to enable the EVM. Using the J2 jumper may cause excessive voltage transients on the SS/ENA pin. Use an external enable signal, instead of J2 jumper.

Figure 2–10. Measured Start-Up Waveforms



Chapter 3

Board Layout

This chapter provides a description of the TPS54314EVM board layout and layer illustrations.

Topic **Page**

3.1 Layout 3-2

3.1 Layout

The top-side (component) layer for the TPS54314EVM is shown in Figure 3–1. The input capacitor (C6), bias decoupling capacitor (C7), and bootstrap capacitor (C5) are all located as close to the IC as possible.

The TPS54314EVM PWB consists of two layers of 1.5 oz. copper. The bottom half of the top layer is used as a power ground plane, while the bottom layer is used as a *quiet* (analog) ground plane. A wide power ground plane is used to keep the power ground current from degrading the load regulation. The two ground planes tie together at U1 to keep the ground current from injecting noise between the analog and power grounds. A total of 10 vias are used to tie the thermal land area under the TPS54314 device to the thermal plane on the backside of the board.

Figure 3–1. Top Side Assembly

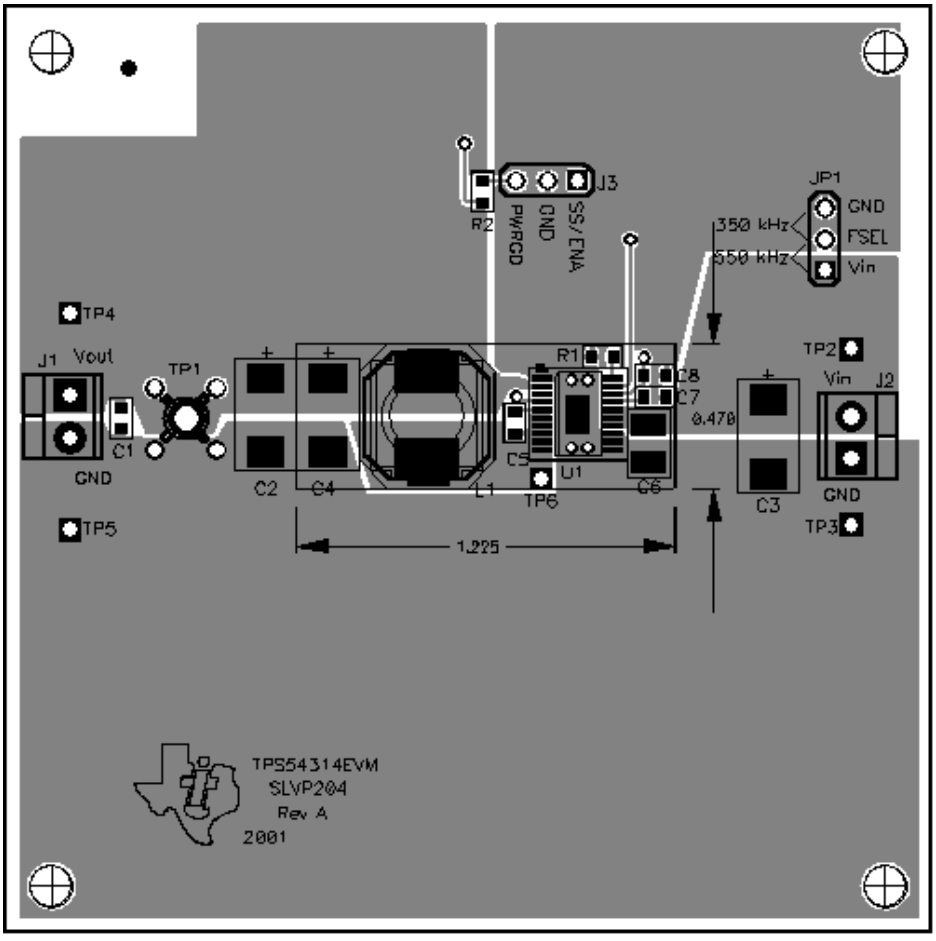


Figure 3–2. Top Side Layout

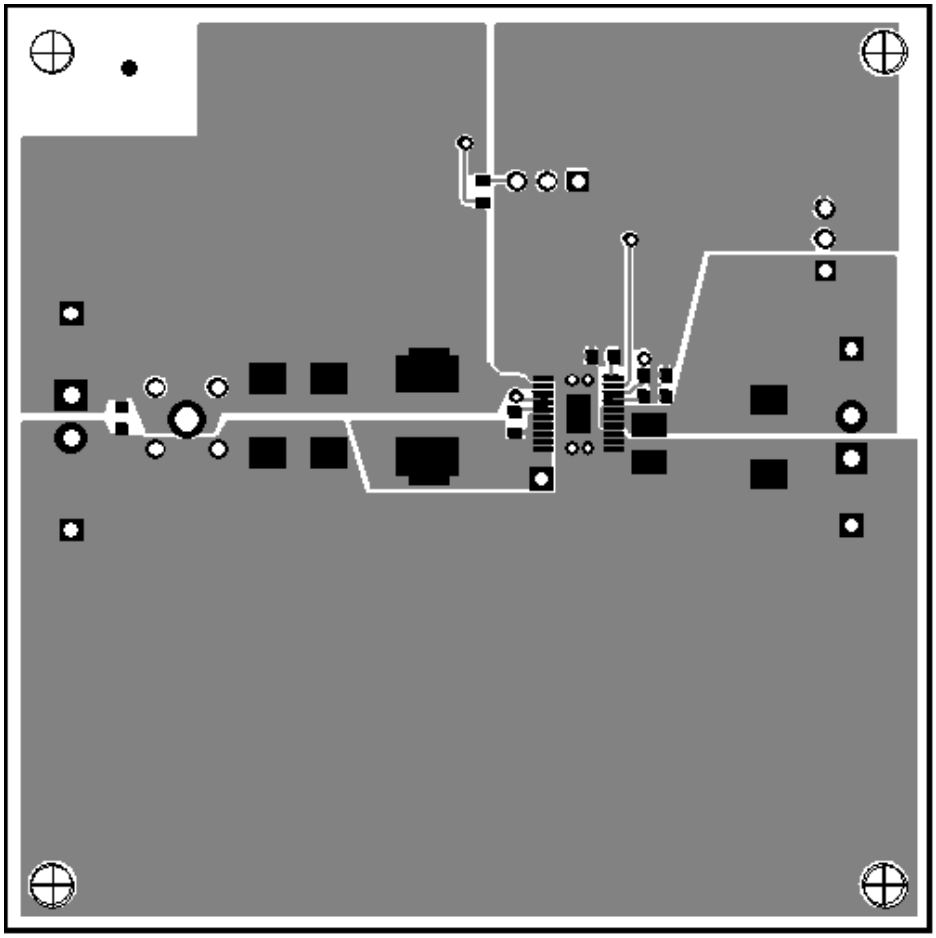
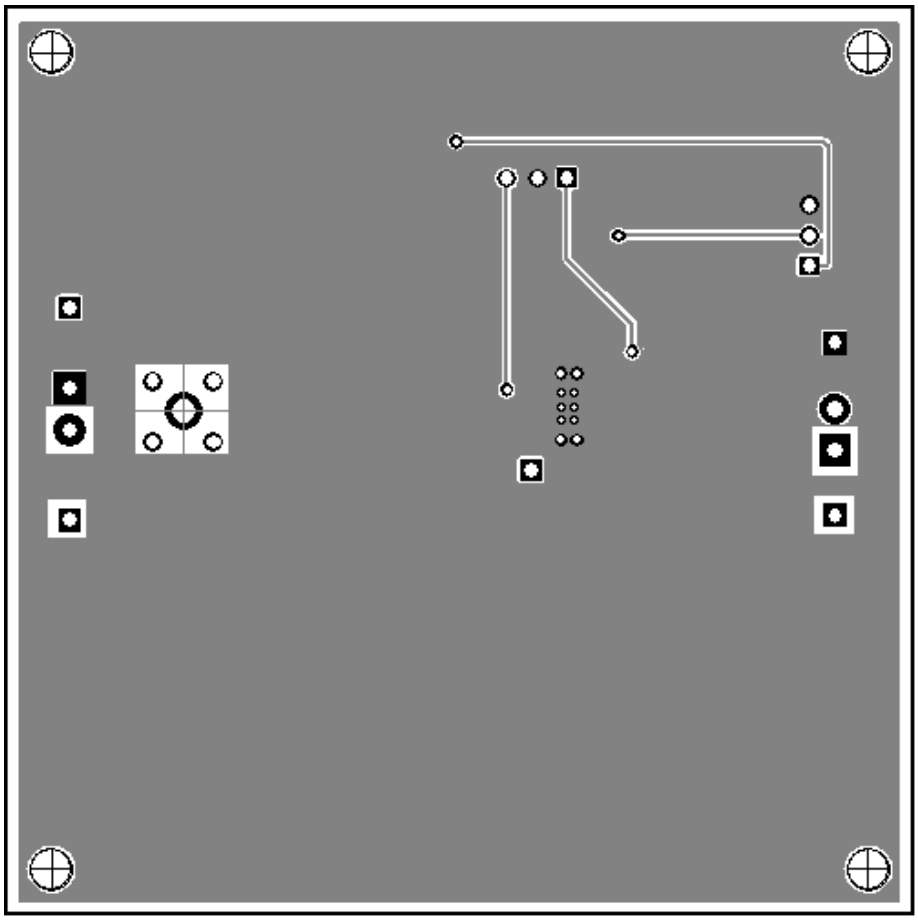


Figure 3–3. Bottom Side Layout



Chapter 4

Schematic and Bill of Materials

The TPS54314EVM schematic and bill of materials are presented in this chapter.

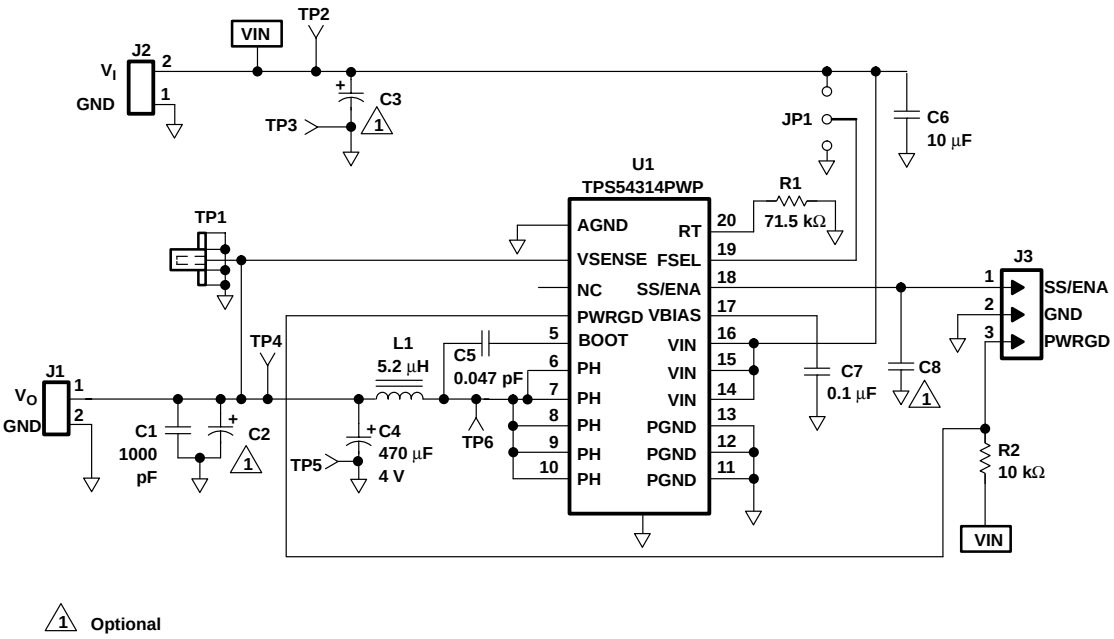
Topic **Page**

4.1 Schematic 4-2

4.2 Bill of Materials 4-3

4.1 Schematic

Figure 4–1. TPS54314EVM Schematic



4.2 Bill of Materials

Table 4–1. TPS54314EVM Bill of Materials

Qty	Ref	Description	Size	MFR	Part Number
1	C1	Capacitor, ceramic, 1000 pF, 25 V, X7r, 10%	603	Murata	GRM39X7R102K25
2	C2, C3	Open	7343 (D)		
1	C4	Capacitor, POSCAP, 470 μF, 4 V, 40 mΩ, 20%	7343 (D)	Sanyo	4TPB470M
1	C5	Capacitor, ceramic, 0.047 μF, 25 V, X7R, 10%	603	Murata	GRM39X7R473K25
1	C6	Capacitor, ceramic, 10 μF, 10 V, X5R, 20%	1210	Taiyo Yuden	LMK325BJ106MN
1	C7	Capacitor, ceramic, 0.1 μF, 25 V, X7R, 10%	603	Murata	GRM39X7R104K25
1	C8	Open	603		
2	J1, J2	Terminal block, 2 pin, 6 A, 3,5 mm	0.27 x 0.25	OST	ED1514
1	J3	Header, 3 pin, 100 mil spacing, (36-pin strip)	0.100 x 3	Sullins	PTC36SAAN
1	JP1	Header, 3 pin, 100 mil spacing, (36-pin strip)	0.100 x 3	Sullins	PTC36SAAN
1	L1	Inductor, SMT, 5.2 μH, 5.5 A, 16 mΩ	0.405 sq	Sumida	CDRH104R–5R2
1	R1	Resistor, chip, 71.5 kΩ, 1/16 W, 1%	603	Std	Std
1	R2	Resistor, chip, 10 kΩ, 1/16 W, 1%	603	Std	Std
1	TP1	Adaptor, 3,5-mm probe clip (or 131-5031-00)	0.2	Tektronix	131-4244-00
3	TP2, TP4, TP6	Test point, red, 1 mm	0.038	Farnell	240–345
2	TP3, TP5	Test Point, Black, 1 mm	0.038	Farnell	240–333
1	U1	IC, IFET power controller, 1.8 V, 3 A	PWP20	TI	TPS54314PWP
1	—	PCB, 3″ x 3″ x 0.062″		Any	SLVP204
2	—	Shunt, 100-mil, black	0.100	3M	929950–00

STANDARD TERMS FOR EVALUATION MODULES

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

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

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

2 *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

WARNING

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

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

NOTE:

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

3 *Regulatory Notices:*

3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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

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

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

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Last updated 10/2025