User's Guide

TPS548A20 SWIFT™ Step-Down Converter Evaluation Module User's Guide

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Trademarks

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1 Introduction

The TPS548A20EVM-737 evaluation module (EVM) uses the TPS548A20 device. The TPS548A20 device is a D-CAP3™ mode, 15-A synchronous buck-converter with integrated MOSFETs. The device provides a fixed 1.2-V output at up to 15 A from a 12-V input bus.

2 Description

The TPS548A20EVM-737 is designed for a regulated 12-V bus to produce a regulated 1.2-V output at up to 15 A of load current. The TPS548A20EVM-737 is designed to demonstrate the TPS548A20 device in a typical low-voltage application while providing a number of test points to evaluate the performance of the TPS548A20 device.

2.1 Typical Applications

- Servers and storage
- Workstations and desktops
- Telecommunication infrastructure

2.2 Features

The TPS548A20EVM-737 features include the following:

- 15-A DC steady-state output current
- Support for a prebias-output voltage at startup
- Jumper, J2, for enable function
- Jumper, J5, for auto-skip and forced-continuous-conduction-mode (FCCM) selection
- Jumper, J7, for extra 5-V input for further power saving purpose
- Convenient test points for probing critical waveforms

3 Electrical Performance Specifications

Table 3-1. TPS548A20EVM-737 Electrical Performance Specifications(1)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS					
Voltage range	V_{IN}	5	12	18	V
Maximum input current	V_{IN} = 5 V, I_O = 8 A		2.5		A
No load input current	V_{IN} = 12 V, I_O = 0 A with auto-skip mode		1		mA
OUTPUT CHARACTERISTICS					
Output voltage VOUT			1.2		V
Output voltage regulation	Line regulation (V_{IN} = 5 V – 14 V) with FCCM		0.2		%
	Load regulation (V_{IN} = 12 V, I_O = 0 A – 8 A) with FCCM		0.5		
Output voltage ripple	V_{IN} = 12 V, I_O = 8 A with FCCM		10		mVpp
Output load current		0		15	A
Output over current			15		A
Soft-start			1		ms
SYSTEMS CHARACTERISTICS					
Switching frequency	V_{IN} = 12 V, 1.2 V / 4 A		1000		kHz
Peak efficiency	V_{IN} = 12 V, 1.2 V / 8 A		88.5		%
Full load efficiency			86.9		%
Operating temperature			25		°C

(1) Jumpers set to default locations, See Section 6.

4 Schematic

Figure 4-1 shows the schematic of the TPS548A20EVM-737 .

The TPS548A20 device is similar to the TPS549A20 device which offers PMBus interface. Table 4-1 lists the differences in pin functions of the TPS548A20 and TPS549A20.

Table 4-1. Device Pin-Out Difference Summary

PIN NO.	PIN NAMES	
	TPS549A20	TPS548A20
26	$\overline{\text{ALERT}}$	NC
27	SDA	GND1
28	SCL	GND1

4.1

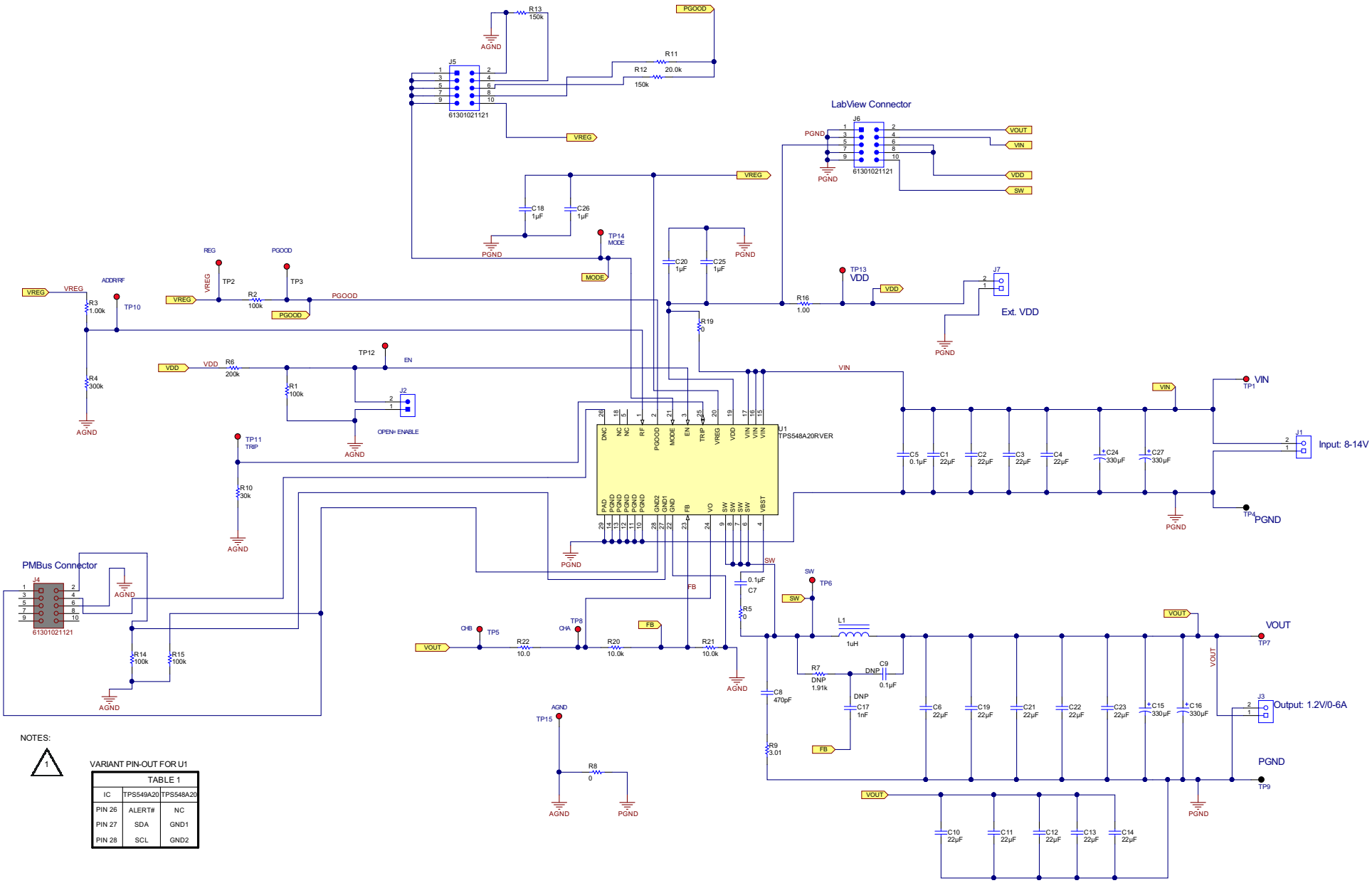

Figure 4-1. TPS548A20EVM-737 Schematic

5 Test Setup

5.1 Test Equipment

Oscilloscope A digital or analog oscilloscope measures the output ripple. The oscilloscope must be set for the following: 1-MΩ impedance, 20-MHz bandwidth, AC coupling, 1-µs per division horizontal resolution, 20-mV per division vertical resolution. Test points TP7 and TP9 measure the output ripple voltage by placing the oscilloscope probe tip through TP7 and holding the ground barrel on TP9 as shown in Figure 5-1. Using a leaded ground connection can induce additional noise due to the large ground loop.

Voltage Source The input voltage source VIN must be a 0 to 14-V variable-DC source capable of supplying 10 ADC. Connect VIN to J1 as shown in Figure 5-2.

Multimeters V1: VIN at TP1 (VIN) and TP4 (GND).
V2: VOUT at TP7 (VOUT) and TP9 (GND).

Output Load The output load must an electronic constant-resistance-mode load capable of 0 to 15 ADC at 1.2 V.

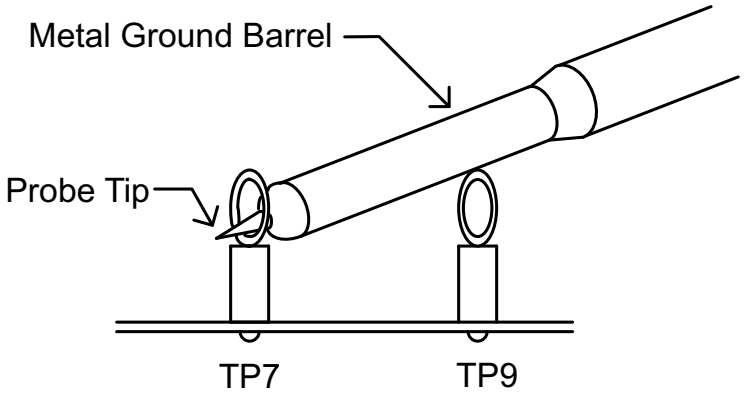

Figure 5-1. Tip and Barrel Measurement for Output Voltage Ripple

Recommended Wire Gauge:

1. V_{IN} to J1 (12-V input)
   - The recommended wire size is 1× AWG number 14 per input connection, with the total length of wire less than 4 feet (2 feet input, 2 feet return).
2. J3 to LOAD
   - The minimum recommended wire size is 2× AWG number 14, with the total length of wire less than 4 feet (2 feet output, 2 feet return).

5.2 Recommended Test Setup

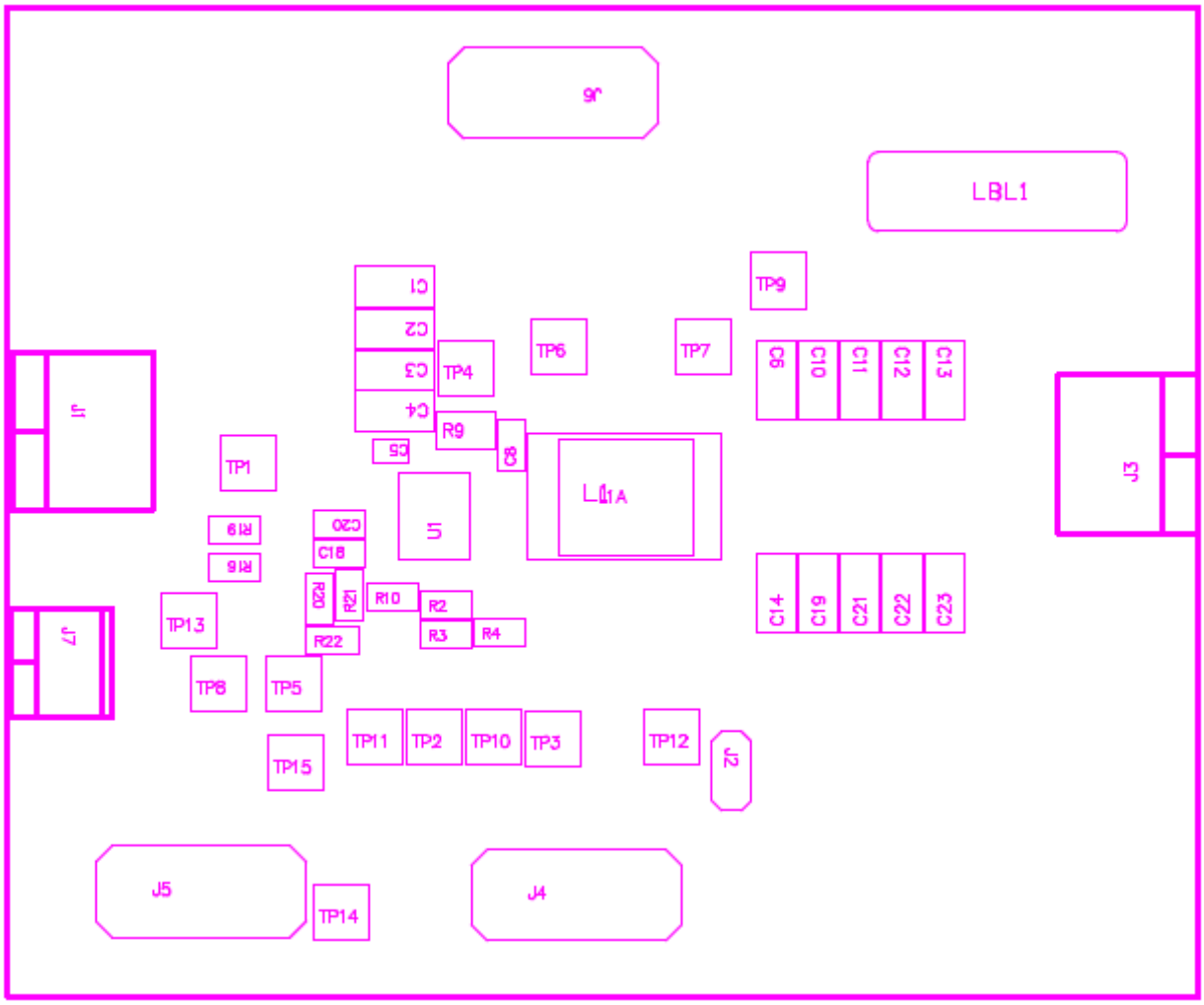

Figure 5-2. TPS548A20EVM-587 Top Layer for Test Setup

Input Connections:

1. Prior to connecting the DC input-source, VIN, TI recommends to limit the source current from VIN to 10 A maximum. Ensure that VIN is initially set to 0 V and connected as shown in Figure 5-2.
2. Connect the voltmeter V1 at TP1 (VIN) and TP4 (GND) to measure the input voltage.

Output Connections:

1. Connect the load to J3 and set the load to constant-resistance-mode to sink 0 ADC before VIN is applied.
2. Connect the voltmeter V2 at TP7 (VOUT) and TP9 (GND) to measure the output voltage.

6 Configurations

All Jumper selections must be made prior to applying power to the EVM. Configure this EVM using the following configuration selections.

6.1 Switching Frequency Selection

Switching frequency can be changed as shown in Table 6-1.

Table 6-1. Switching Frequency Selection

SWITCHING FREQUENCY(1) (f_{SW}) (kHz)	RESISTOR DIVIDER RATIO (R_{DR})	EXAMPLE RF FREQUENCY COMBINATIONS	
		R_{RF_H} (kΩ)	R_{RF_L} (kΩ)
1000	> 0.557	1	300
850	0.461	180	154
750	0.375	200	120
600	0.297	249	105
500	0.229	240	71.5
400	0.16	249	47.5
300	0.096	255	27
200	< 0.041	270	11.5

(1) Default Setting: 1 MHz.

For different switching frequency setting, please change R3 and R4 as shown in Table 6-1.

6.2 Mode Selection

The MODE can be set by J5.

Table 6-2. Mode Selection

JUMPER SET TO:	MODE SELECTION
1 to 2 pin shorted	FCCM with 2x RC time constant
3 to 4 pin shorted(1)	FCCM(2) with 1x RC time constant(1)
5 to 6 pin shorted	FCCM(2) with 2x RC time constant
7 to 8 pin shorted	Auto-skip mode with 2× RC time constant
9 to 10 pin shorted	Auto-skip mode with 1× RC time constant

(1) Default setting.
(2) The device enters FCCM after PGOOD goes high.

6.3 VDD Pin Supply Selection

The controller can be enabled and disabled by J7.

Table 6-3. Enable Selection

SET ON CONNECTION	ENABLE SELECTION
R19 = 0 Ω(1)	VDD pin connected to VIN pins(1)
R19 = Open	VDD pin disconnected to VIN pins

(1) Default setting: the VDD pin connected to the VIN pins through R19.

For power-up, input J7 with proper voltage. The VDD pin input voltage range is from 4.5 V to 25 V.

7 Test Procedure

7.1 Line and Load Regulation and Efficiency Measurement Procedure

1. Set up the EVM as described in Section 5 and Figure 5-2.
2. Ensure the load is set to constant-resistance mode and to sink at 0 ADC.
3. Ensure all jumper setting are configured as shown in Section 6.
4. Ensure the jumper provided in the EVM shorts on J2 before VIN is applied.
5. Increase VIN from 0 to 12 V. Use V1 to measure input voltage.
6. Remove the jumper on J2 to enable the controller.
7. Use V2 to measure the VOUT voltage.
8. Vary the load from 0 to 10 ADC, VOUT must remain in load regulation.
9. Vary VIN from 8 to 14 V, VOUT must remain in line regulation.
10. To disable the converter, place the jumper on J2.
11. Decrease the load to 0 A
12. Decrease VIN to 0 V.

7.2 Control-Loop Gain and Phase-Measurement Procedure

The TPS548A20EVM-737 contains a 10-Ω series resistor in the feedback loop for loop response analysis.

1. Set up the EVM as described in Section 5 and Figure 5-2.
2. Connect the isolation transformer to the test points marked TP5 and TP8.
3. Connect the input-signal amplitude-measurement probe (channel A) to TP10. Connect the output-signal amplitude-measurement probe (channel B) to TP11.
4. Connect the ground lead of channel A and channel B to TP15.
5. Inject around 20 mV or less signal through the isolation transformer.
6. To measure control-loop gain and phase margin, change the frequency from 100 Hz to 1 MHz using a 10-Hz or less post filter.
7. Disconnect the isolation transformer from the bode-plot test points before making other measurements.
   - Signal injection into feedback can interfere with the accuracy of other measurements.

7.3 List of Test Points

Table 7-1. Test Point Functions

TEST POINTS	NAME	DESCRIPTION
TP1	VIN	Converter input supply voltage
TP2	VREG	LDO voltage
TP3	PGOOD	Power good output
TP4	PGND	Power ground
TP5	CHB	Input B for loop injection
TP6	SW	Switch Node
TP7	VOUT	VOUT terminal +
TP8	CHA	Input A for loop injection
TP9	PGND	Power ground
TP10	RF	RF pin
TP11	TRIP	TRIP pin
TP12	EN	Enable pin
TP13	VDD	VDD pin
TP14	MODE	MODE pin
TP15	AGND	Analog ground

7.4 Equipment Shutdown

Follow these steps when shutting down the equipment.

1. Shut down load
2. Shut down VIN

8 EVM Assembly Drawing and PCB Layout

The following figures show the design of the TPS548A20EVM-737 printed circuit board (see Figure 8-1, Figure 8-2, Figure 8-3, Figure 8-4, Figure 8-5, Figure 8-6, Figure 8-7, and Figure 8-8). The EVM has been designed using a six-layer, 2-oz copper-circuit board.

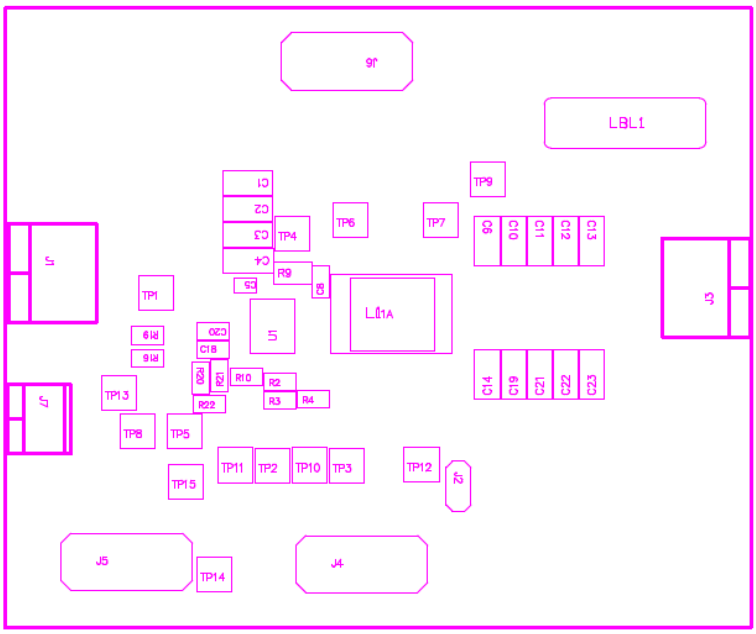

Figure 8-1. TPS548A20EVM-587 Top-Layer Assembly Drawing

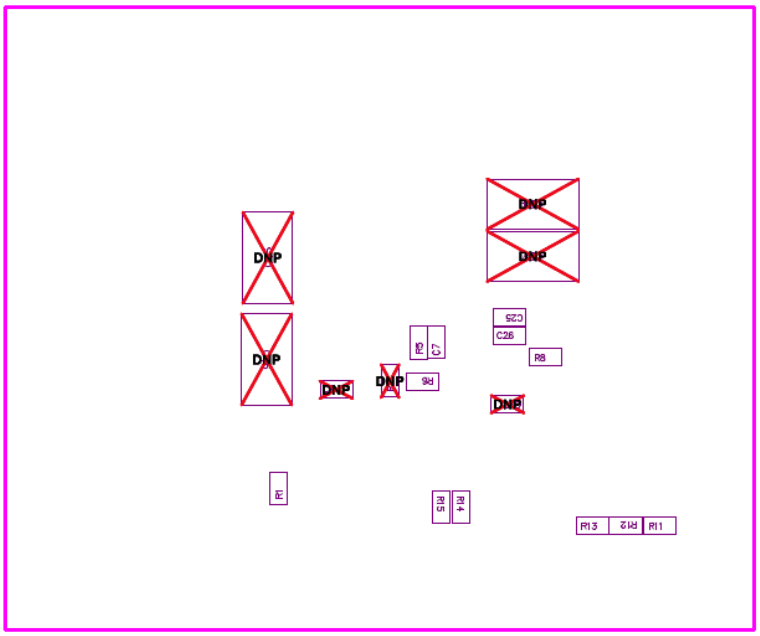

Figure 8-2. TPS548A20EVM-587 Bottom-Layer Assembly Drawing

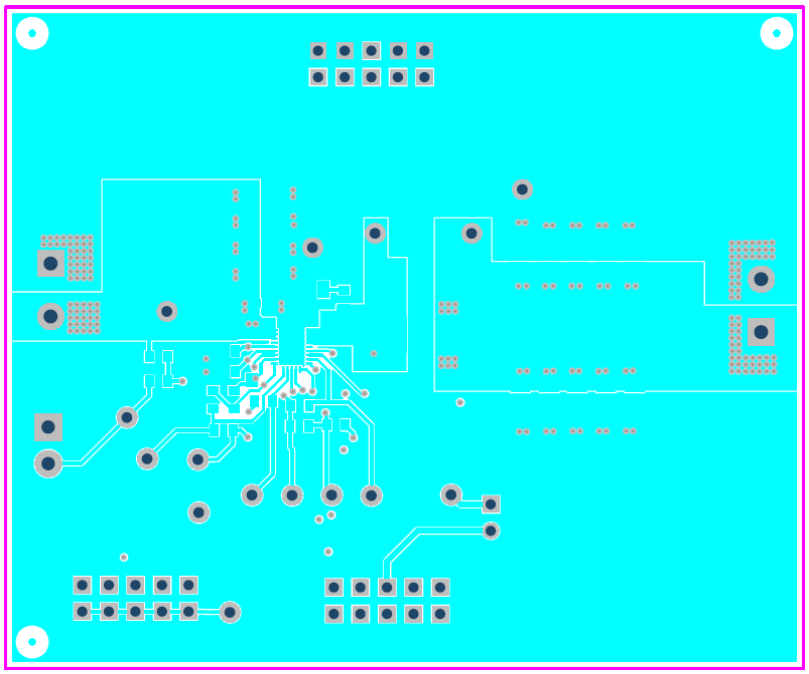

Figure 8-3. TPS548A20EVM-587 Top Layer, Copper

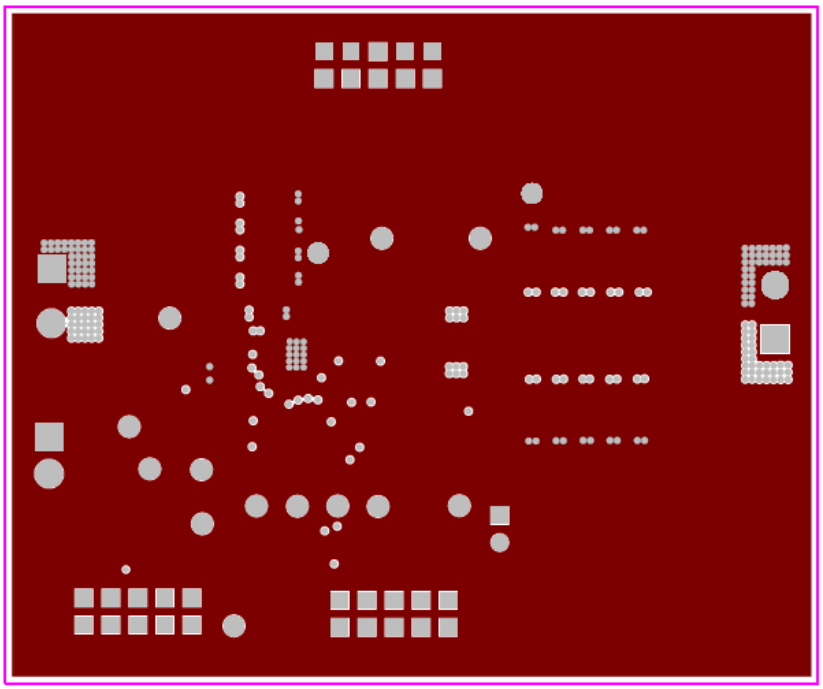

Figure 8-4. TPS548A20EVM-587 Layer Two, Copper

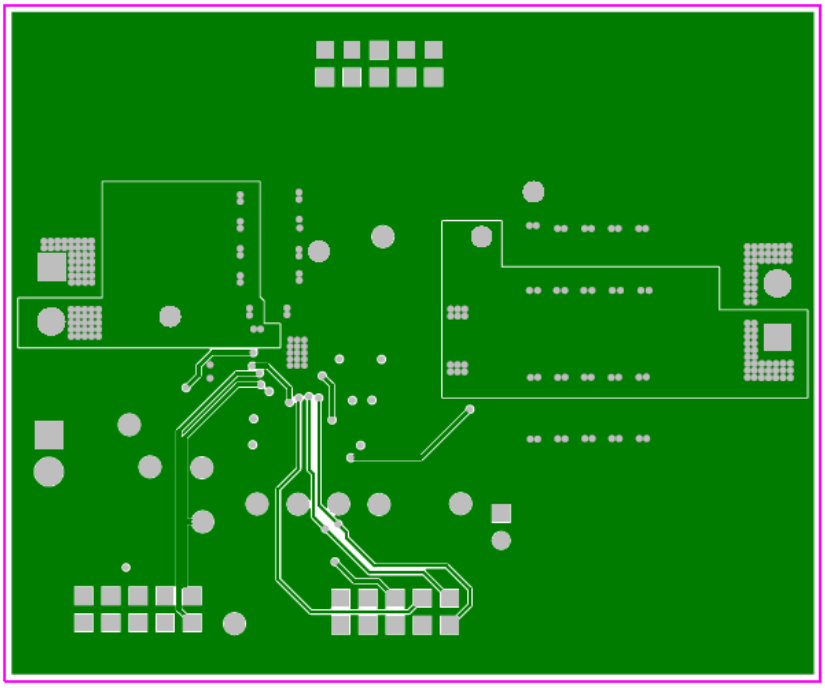

Figure 8-5. TPS548A20EVM-587 Layer Three, Copper

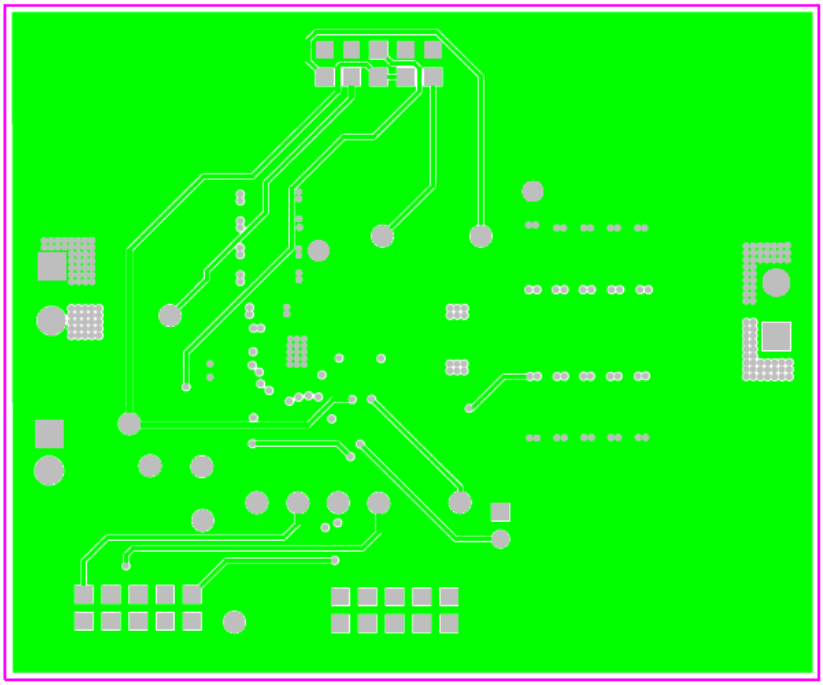

Figure 8-6. TPS548A20EVM-587 Layer Four, Copper

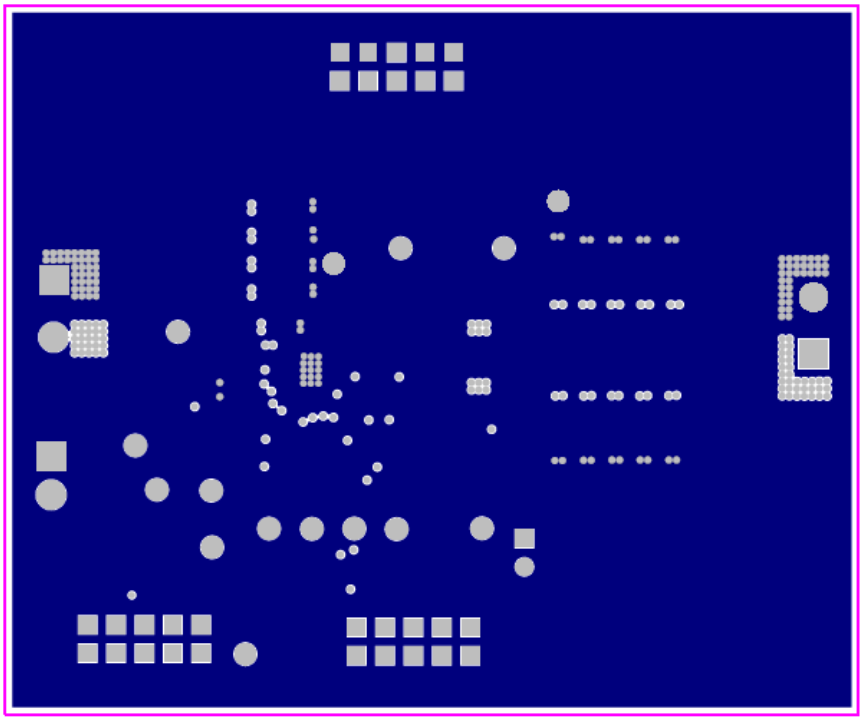

Figure 8-7. TPS548A20EVM-587 Layer Five, Copper

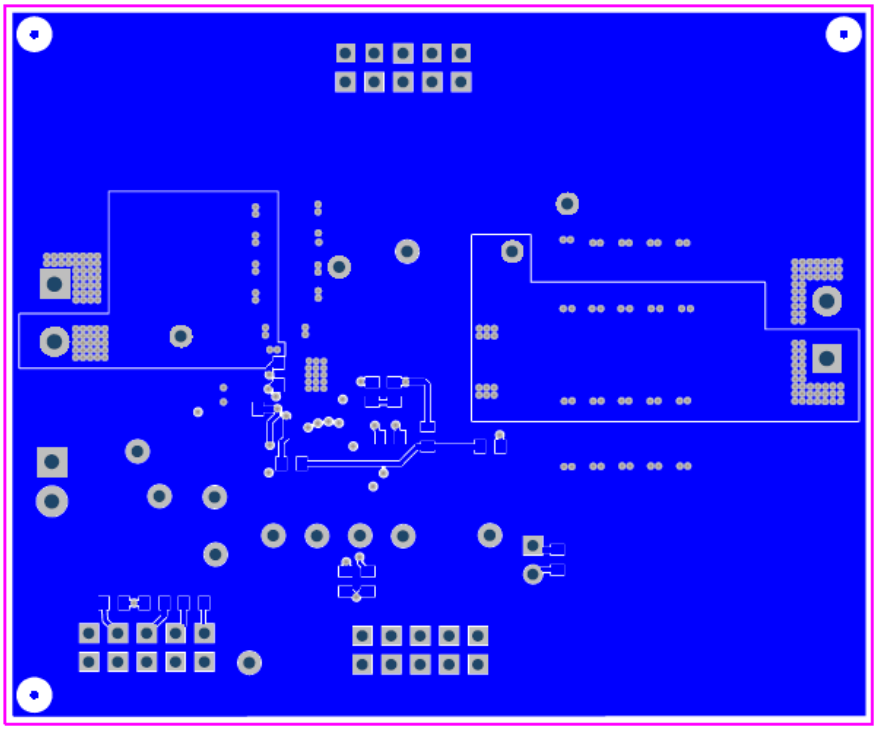

Figure 8-8. TPS548A20EVM-587 Bottom Layer, Copper

9 Bill of Materials

Table 9-1. EVM Components List (Based on the Schematic, See Figure 4-1)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C1, C2, C3, C4	4	22 µF	Capacitor, ceramic, 25 V, X5R, 10%	1206	GRM31CR61E226KE15L	Murata
C5	1	0.1 µF	Capacitor, ceramic, 0.1 µF 25 V 10% X5R 0402	0402	GRM155R61E104KA87D	Murata
C6, C10, C11, C12, C13, C14, C19, C21, C22, C23	10	22 µF	Capacitor, ceramic, 6.3 V, X5R, 20%	1206	GRM31CR60J226KE19L	Murata
C7	1	0.1 µF	Capacitor, ceramic, 0.1 µF 50 V 10% X7R 0603	0603	GRM188R71H104KA93D	Murata
C8	1	470 pF	Capacitor, ceramic, 470 pF 50 V 10% X7R 0603	0603	GRM188R71H471KA01D	Murata
C9, C17	0	Open	Capacitor, ceramic, 50 V, X7R, 10%	0603	Standard	Standard
C15, C16, C24, C27	0	Open	Capacitor, POSCAP, SMT, 2.5 V, 330 µF, 8 mΩ	7343(D)	2R5TPE330M9 or 6TPE330MIL	Sanyo
C18, C20, C25, C26	4	1 µF	Capacitor, ceramic, 1 µF 16 V 10% X7R 0603	0603	GRM188R71C105KA12J	Murata
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
J1, J3	2	ED120/2DS	Terminal Block, 2-pin, 15-A, 5,1 mm	0.4 × 0.35 inch	ED120/2DS	OST
J2	1	PEC02SAAN	Header, Male 2-pin, 100-mil spacing,	0.1 × 2 inch	PEC02SAAN	Sullins
J4, J5, J6	3	PEC05DAAN	Header, Male 2×5-pin, 100-mil spacing	0.1 × 2 × 5 inch	PEC05DAAN	Sullins
J7	1	ED555/2DS	Terminal Block, 2-pin, 6-A, 3,5 mm	0.27 × 0.25 inch	ED555/2DS	OST
L1	1	1 µH	Inductor, Power chokes SMD	6,6 × 7,1 mm	PIMB065T-1R0MS	Cyntec
LBL1	1		Thermal transfer printable labels, 0.650 (W) × 0.2 inch (H) — 10,000 per roll	PCB Label 0.65 (H) × 0.2 inch (W)	THT-14-423-10	Brady
R1, R2, R14, R15	4	100k	Resistor, 100 kΩ, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R3	1	1 kΩ	Resistor, 1 kΩ, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R4	1	300 kΩ	Resistor, 300 kΩ, 1%, 0.1 W, 0603	0603	RC0603FR-07300KL	Yageo America
R5, R8, R19	3	0	Resistor, 0 Ω, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R6	1	200 kΩ	Resistor, 200 kΩ, 1%, 0.1 W, 0603	0603	CRCW0603200KFKEA	Vishay-Dale
R7	0	Open	Resistor, Chip, 1/16 W, 1%	0603	Standard	Standard
R9	1	3.01 Ω	Resistor, 3.01 Ω, 1%, 0.125 W, 0805	0805	CRCW08053R01FKEA	Vishay-Dale
R10	1	57.6 kΩ	Resistor, 57.6 kΩ, 1%, 0.1 W, 0603	0603	RC0603FR-0757K6L	Yageo America
R11	1	20.0 kΩ	Resistor, 20.0 kΩ, 1%, 0.1 W, 0603	0603	CRCW060320K0FKEA	Vishay-Dale
R12, R13	2	150 kΩ	Resistor, 150 kΩ, 1%, 0.1 W, 0603	0603	CRCW0603150KFKEA	Vishay-Dale
R16	1	1 Ω	Resistor, 1 Ω, 1%, 0.1 W, 0603	0603	CRCW06031R00FKEA	Vishay-Dale
R20, R21	2	10 kΩ	Resistor, 10 kΩ, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R22	1	10 Ω	Resistor, 10 Ω, 1%, 0.1 W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale
TP1, TP2, TP3, TP5, TP6, TP7, TP8, TP10, TP11, TP12, TP13, TP14, TP15	13	5000	Test Point, red, thru hole color keyed	0.1 × 0.1 inch	5000	Keystone
TP4, TP9	2	5001	Test point, black, thru hole color keyed	0.1 × 0.1 inch	5001	Keystone
U1	1	TPS548A20RVE	High-performance, 15-A single sync. step-down converter		TPS548A20RVE	TI

10 Revision History

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

Changes from Revision * (December 2015) to Revision A (August 2021)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document	2
• Updated user's guide title	2

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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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。

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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
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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.

6. *Disclaimers:*

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

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

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

8. *Limitations on Damages and Liability:*

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

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

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

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

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