TPS568230EVM evaluation module

This user's guide contains information for the TPS568230EVM evaluation module as well as the TPS568230 dc/dc converter. Also included are the performance specifications, board layout, schematic, and the List of Materials for the TPS568230EVM.

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1 Introduction

TPS568230 dc/dc converter is a synchronous buck converter designed to provide up to a 8-A output. The input (VIN) is rated for 4.5 V to 18 V. The TPS568230 uses a proprietary DCAP3 Control mode. Rated input voltage and output current range for the evaluation module are given in Table 1. The high-side and low-side MOSFETs are incorporated inside the TPS568230 package along with the gate-drive circuitry. An external divider allows for an adjustable output voltage. Additionally, the TPS568230 provides 1.3ms internal soft start or external soft start, under voltage lockout inputs and a power good output.

Table 1. Input voltage and output current range summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS568230EVM	4.5 V to 18 V	0 A to 8 A

2 Performance Specification Summary

A summary of the TPS568230EVM performance specifications is provided in Table 2. Specifications are given for an input voltage of VIN = 12 V and an output voltage of 1.05 V, unless otherwise specified. The TPS568230EVM is designed and tested for VIN = 4.5 V to 18 V. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 2. Summary of performance

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage		4.5	12	18	V
Output voltage setpoint			1.05		V
FB voltage	TJ = 25°C	594	600	606	mV
Output current range		0		8	A
Soft start time	External soft start time		2.6		ms
Operating frequency			600k		Hz
Mode	Light load operating mode		ECO		
Over current	Valley current set point		9.8		A

TPS568230 supports 9 different kinds of mode by selecting divider resister on mode pin. Please refer Table 3.

In this TPS568230EVM board, mode can be selected to 600kHz ECO, 600kHz OOA or 600kHz FCCM by Mode Jumper. If you want to select other mode, please replace mode divider resister according to below table.

Table 3. Mode Table

R_Top(kΩ)	R_Bottom (kΩ)	LIGHT LOAD OPERATION	FREQUENCY (kHz)
330	5.1	Eco	600
330	15	Eco	800
330	27	Eco	1000
200	27	OOA	600
150	33	OOA	800
160	51	OOA	1000
110	51	FCCM	600
75	51	FCCM	800
51	51	FCCM	1000

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3 Schematic and List of Materials

This section presents the TPS568230EVM schematic and List of Materials.

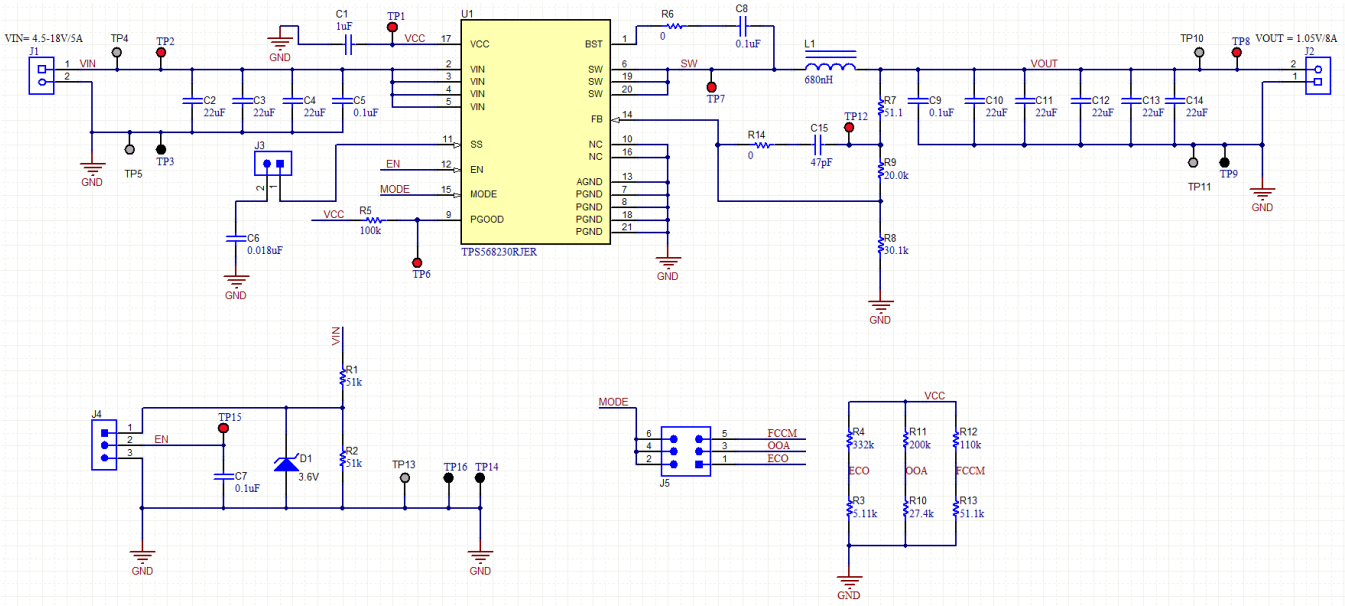


Figure 1. Schematic

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Table 4. TPS568230EVM List of Materials

DES	QTY	DESCRIPTION	PART NUMBER	MAN
C1	1	Capacitor, ceramic, 1 µF, 25 V, ±10%, X5R, 0603	C1608X5R1E105K080AC	TDK
C3, C4	2	Capacitor, ceramic, 22 µF, 35 V, ±20%, X5R, 1206	C3216X5R1V226M160AC	TDK
C5, C7, C8, C9	4	Capacitor, ceramic, 0.1 µF, 50 V, ±10%, X7R, 0603	C1608X7R1H104K080AA	TDK
C6	1	Capacitor, ceramic, 0.018 µF, 16 V, ±10%, X7R, 0603	GRM188R71C183KA01D	MuRata
C10, C11, C12, C13, C14	5	Capacitor, ceramic, 22 µF, 10 V, +±20%, X7S, 1206	C3216X7S1A226M160AC	TDK
C15	1	Capacitor, ceramic, 47 pF, 50 V, +±5%, C0G/NP0, 0603	06035A470JAT2A	AVX
D1	1	Diode, Zener, 3.6 V, 500 mW, SOD-123	MMSZ4685T1G	ON Semiconductor
H1, H2, H3, H4	4	Bumpon, hemisphere, 0.44 X 0.20, clear	SJ-5303 (CLEAR)	3M
J1, J2	2	Terminal block, 5.08 mm, 2x1, brass, TH	ED120/2DS	On-Shore Technology
J3	1	Header, 100 mil, 2x1, tin, TH	PEC02SAAN	Sullins Connector Solutions
J4	1	Header, 100 mil, 3x1, tin, TH	PEC03SAAN	Sullins Connector Solutions
J5	1	Header, 100 mil, 3x2, tin, TH	PEC03DAAN	Sullins Connector Solutions
L1	1	Inductor, shielded drum core, Superflux, 680 nH, 17 A, 0.0035 Ω, SMD	744311068	Wurth Elektronik
R1	1	Resistor, 120 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603120KJNEA	Vishay-Dale
R2	1	Resistor, 51 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060351K0JNEA	Vishay-Dale
R3	1	Resistor, 5.11 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW06035K11FKEA	Vishay-Dale
R4	1	Resistor, 332 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603332KFKEA	Vishay-Dale
R5	1	Resistor, 100 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603100KFKEA	Vishay-Dale
R6, R14	2	Resistor, 0 Ω, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale
R7	1	Resistor, 51.1 Ω, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060351R1FKEA	Vishay-Dale
R8	1	Resistor, 30.1 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060330K1FKEA	Vishay-Dale
R9	1	Resistor, 20.0 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060320K0FKEA	Vishay-Dale
R10	1	Resistor, 27.4 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060327K4FKEA	Vishay-Dale
R11	1	Resistor, 200 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603200KFKEA	Vishay-Dale
R12	1	Resistor, 110 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603110KFKEA	Vishay-Dale
R13	1	Resistor, 51.1 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060351K1FKEA	Vishay-Dale
SH-J1, SH-J2, SH-J3	3	Shunt, 100 mil, gold plated, black	SNT-100-BK-G	Samtec
TP1, TP2, TP6, TP7, TP8, TP12, TP15	7	Test point, miniature, red, TH	5000	Keystone
TP3, TP9, TP14, TP16	4	Test point, miniature, black, TH	5000	Keystone
TP4, TP5, TP10, TP11, TP13	5	Terminal, turret, TH, Triple	1598-2	Keystone
U1	1	4.5-V to 18-V input, 8-A synchronous step-down voltage regulator, RJE0020A (VQFN-HR-20)	TPS568230RJER	Texas Instruments

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4 Board Layout

This section provides a description of the TPS568230EVM board layout and layer illustrations. The board layout for the TPS568230EVM is shown in below figures. The top-side layer of the EVM is laid out in a manner typical of a user application. The top and bottom layers are 2-oz copper, and internal layers are 1-oz copper.

The top layer contains the main power traces for VIN, VOUT, and SW. Also on the top layer are connections for the remaining pins of the TPS568230 and the majority of the signal traces. There is a large area filled with ground. The internal layer-1 and layer-2 are ground plane. The bottom layer is another ground plane with some additional signal. The top-side ground traces are connected to the bottom and internal ground planes with multiple vias placed around the board.

The input decoupling capacitors and bootstrap capacitor are all located as close to the IC as possible. Additionally, the voltage set point resistor divider components are kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation. For the TPS568230, an additional input bulk capacitor may be required, depending on the EVM connection to the input supply. Critical analog circuits such as the voltage set point divider, EN resistor, SS capacitor, MODE resistor, and AGND pin are terminated to quiet analog ground island.

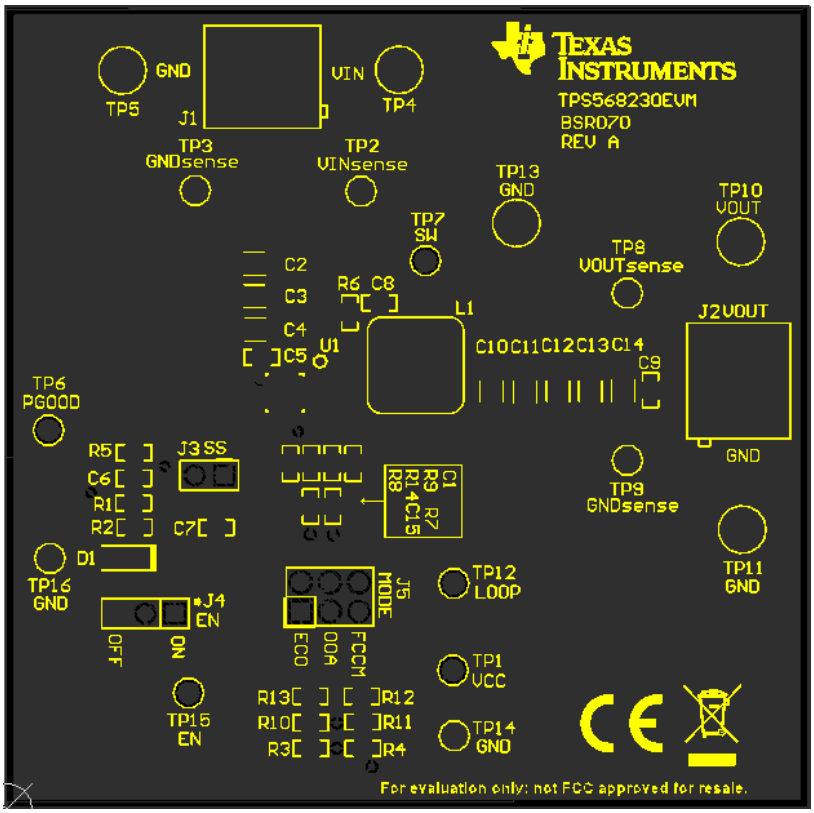


Figure 2. Component Placements

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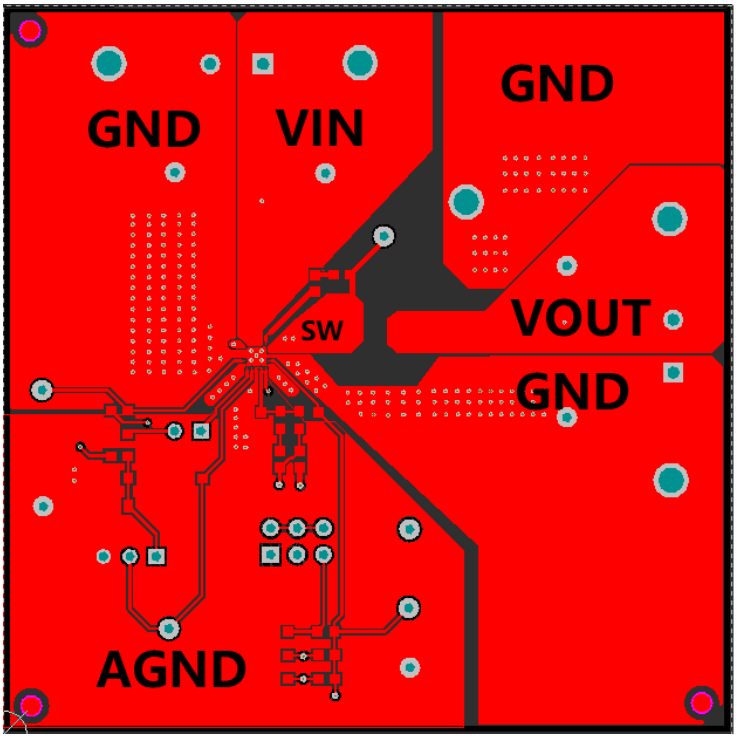


Figure 3. Top Layer

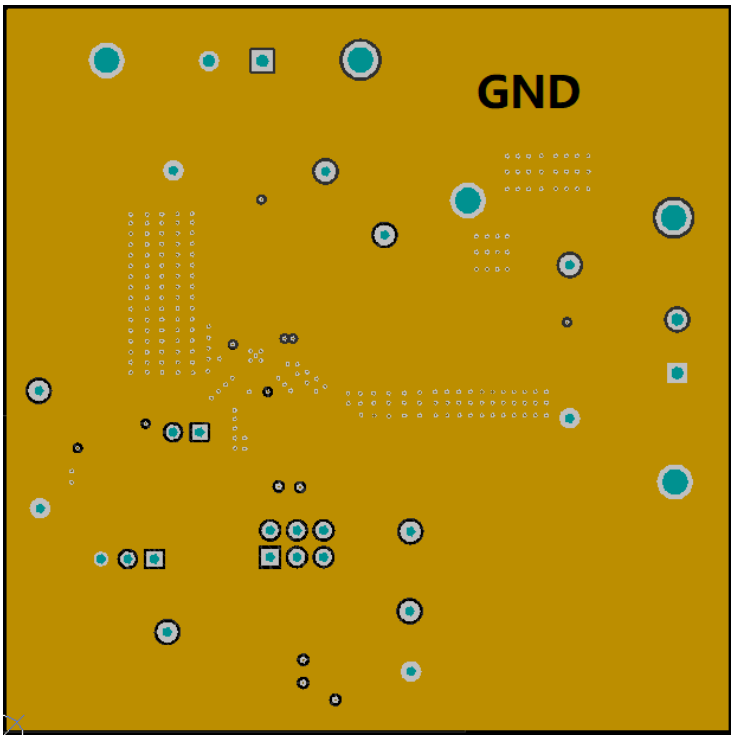


Figure 4. Internal Layer1

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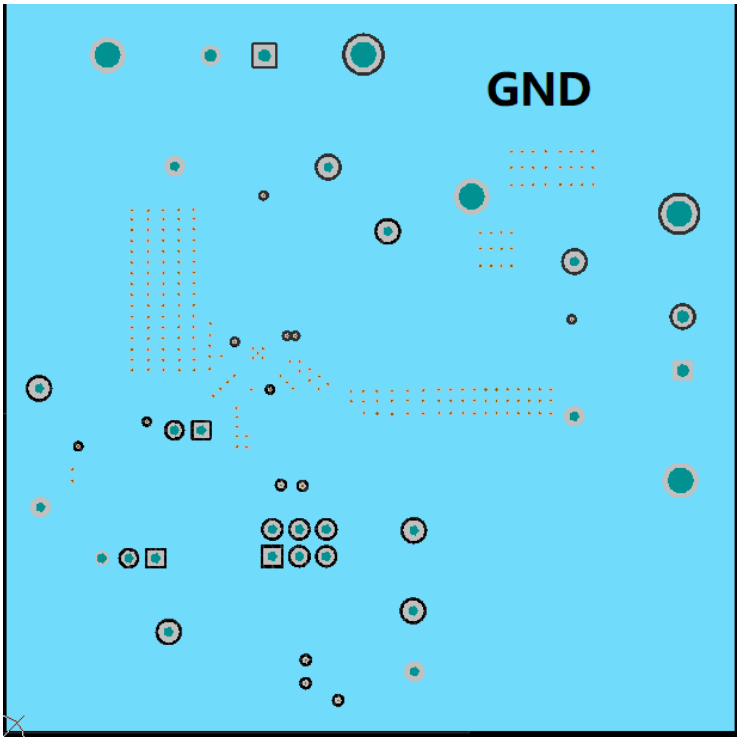


Figure 5. Internal Layer2

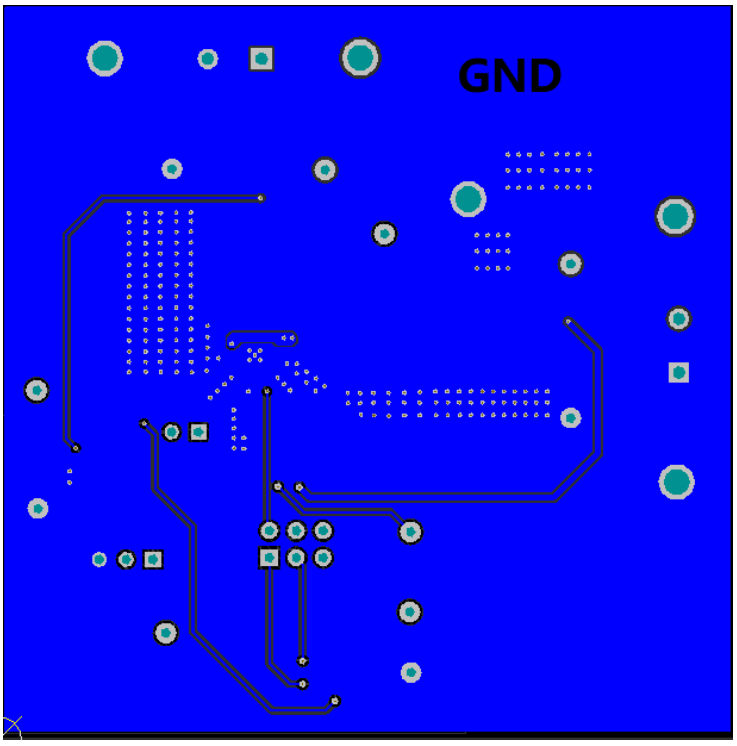


Figure 6. Bottom Layer

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Figure 7 and Figure 8 are high revolution images of the EVM board.

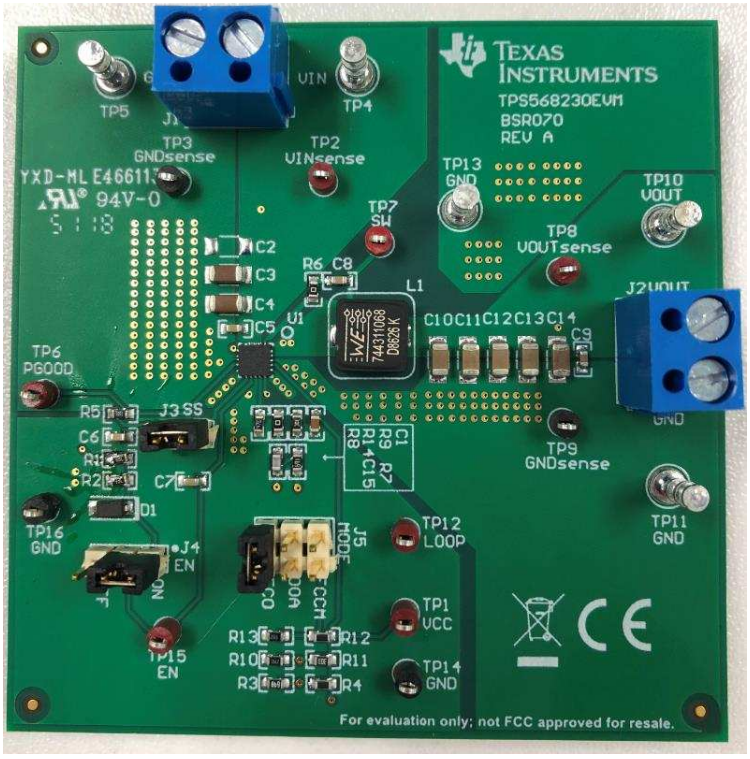


Figure 7. EVM Front View

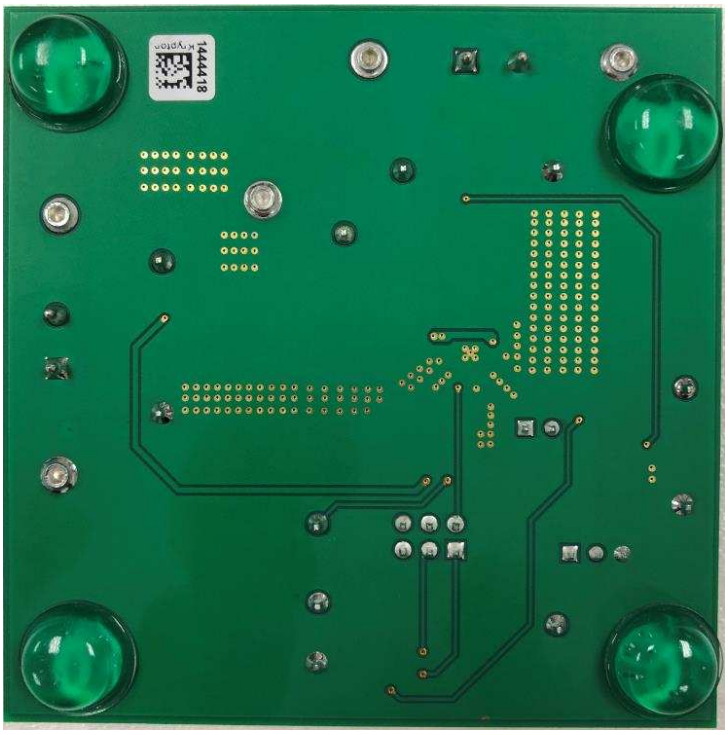


Figure 8. EVM Back View

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5 Bench Test Setup conditions

This section describes how to properly connect, set up, and use the TPS568230EVM evaluation module.

5.1 Headers Description and Jumper Placement.

The TPS568230EVM header description is as Figure 9. A power supply capable of supplying greater than 4 A must be connected to J1 through a pair of 20-AWG wires or better. The load must be connected to J2 through a pair of 20-AWG wires or better. The maximum load current capability is 8 A. Wire lengths must be minimized to reduce losses in the wires. Test point TP2 provides a place to monitor the VIN input voltages with TP3 providing a convenient ground reference. TP8 is used to monitor the output voltage with TP9 as the ground reference.

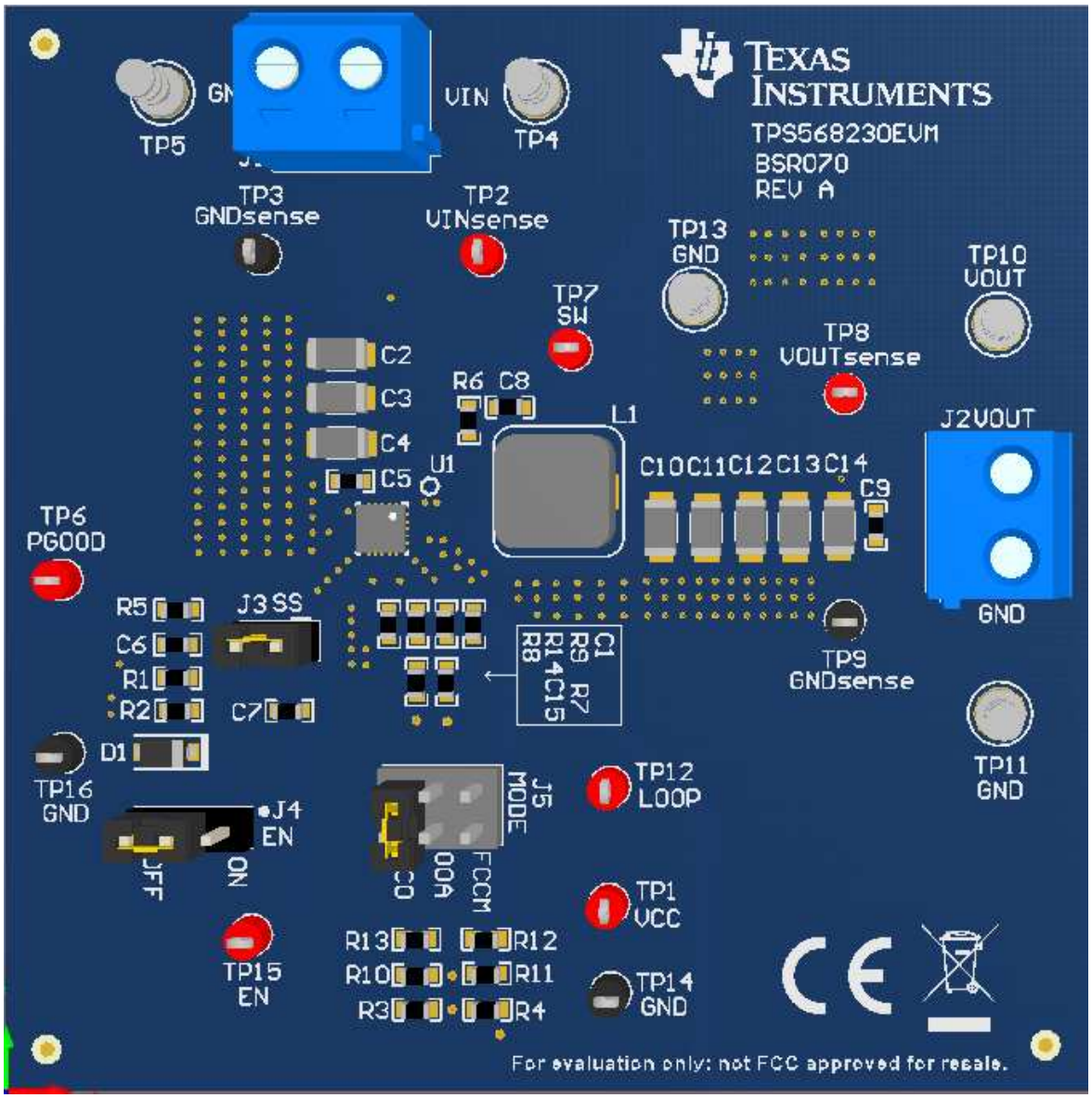


Figure 9. Headers Description and Jumper Placement

Connector and test point description is as Table 5.

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Table 5. Input and Output Connection

#	FUNCTION	DESCRIPTION
J1	VIN connector	VIN power
J2	VOUT connector	VOUT power
J3	Internal/external Soft Start selection	When short J3, IC uses external SS by charging the cap C6. When float J3, IC uses internal SS.
J4	Enable control	Middle pin is Buck Enable PIN. When this PIN is floating, the IC is disable. When the jumper short EN on, IC is enable. When the jumper short EN off, IC is disable.
J5	Mode selection	This EVM provides three kinds of mode. When short FCCM, IC works with forced continue current mode. Frequency is 600kHz. When short OOA, IC works with out of audio mode, frequency is 600kHz. When short ECO, IC works with pulse skip mode, frequency is 600kHz.
TP1	VCC test point	Test VCC
TP2	VIN test point	Test VIN
TP3/5/9/11/13/16/17	GND connector	
TP4	VIN connector	VIN power
TP6	PGOOD test point	Test PGOOD
TP7	SW test point	Test SW
TP8	VOUT test point	Test VOUT
TP10	VOUT connector	VOUT loading
TP12	Loop test point	test loop
TP15	Enable test point	test Enable signal

5.2 Power-Up Procedure

POWER-UP with external Enable Buck signal.

1, Select Mode function.

2, Apply 4.5 V~18 V to J1.

3, Apply 1.4 V~3.3 V to J4 middle pin(enable pin).

4, Apply loading to J2 output connector.

POWER-UP with V_{IN} control Enable Buck signal.

1, Select Mode function.

2, Connect J4 middle pin and left pin together with Jumper cap.

3, Apply 4.5 V~18 V to J1.

4, Apply loading to the J2 output connectors.

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6 Test Waveform

6.1 Power Up

Figure 10 and Figure 11 show the start-up waveforms with 0-A and 8-A loading for the TPS568230EVM board. The applied input voltage is 12 V. Once the EN is high, Vout ramps up.

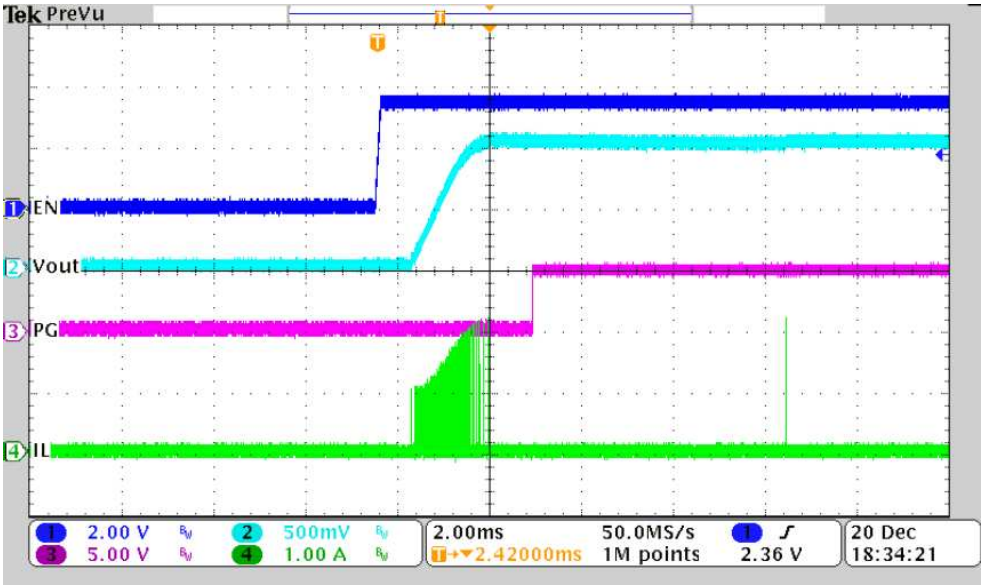


Figure 10. Power Up with 0 A

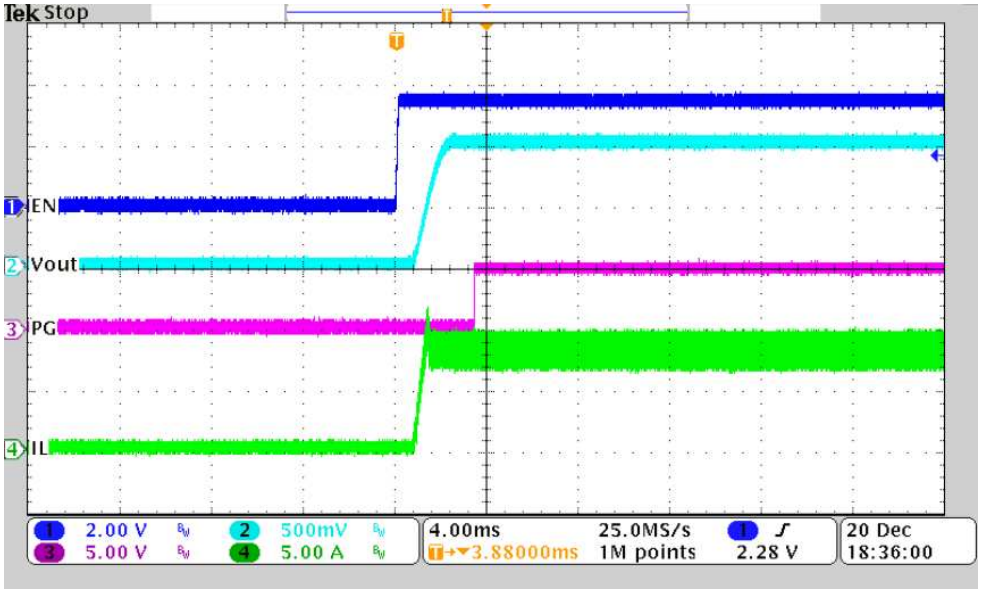


Figure 11. Power Up with 8 A

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6.2 Power Down

Figure 12 and Figure 13 show the power down waveforms for the TPS568230EVM board. The applied input voltage is 12 V. Once the EN is down, Vout ramps down.

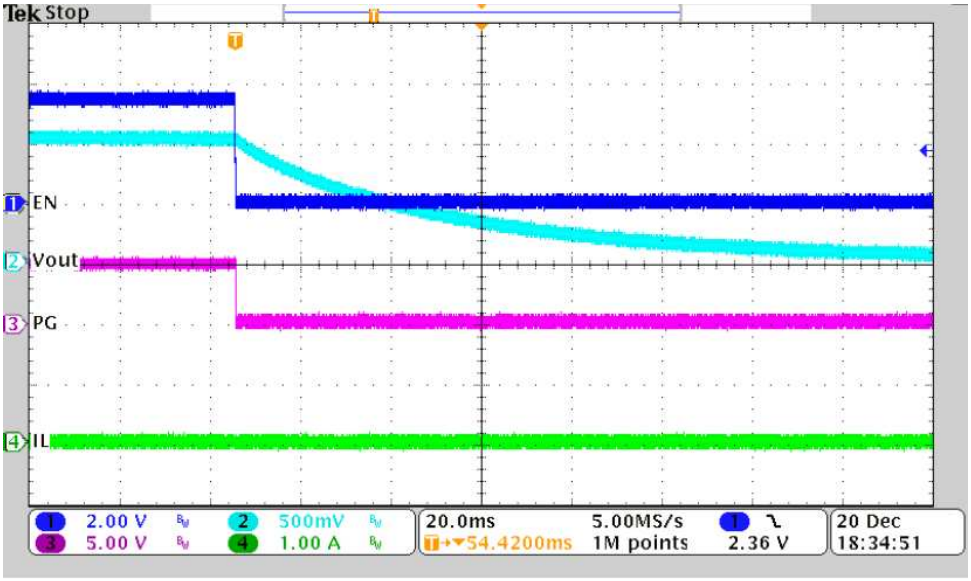


Figure 12. Power Down with 0 A

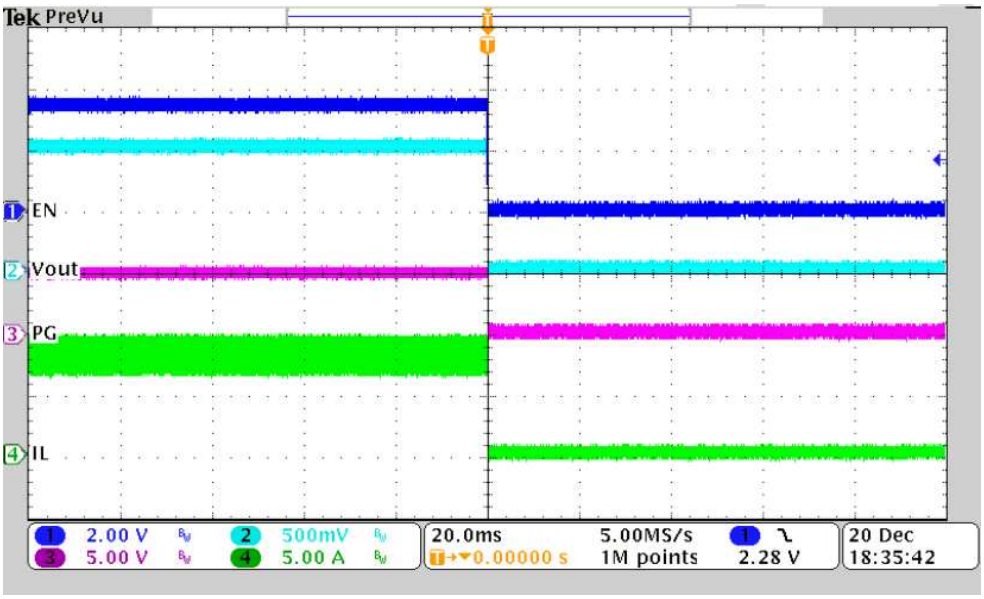


Figure 13. Power Down with 8 A

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6.3 Output Voltage Ripple

Figure 14 and Figure 15 show the output voltage ripple with 0 A and 8 A for the TPS568230EVM board. The input voltage is 12 V.

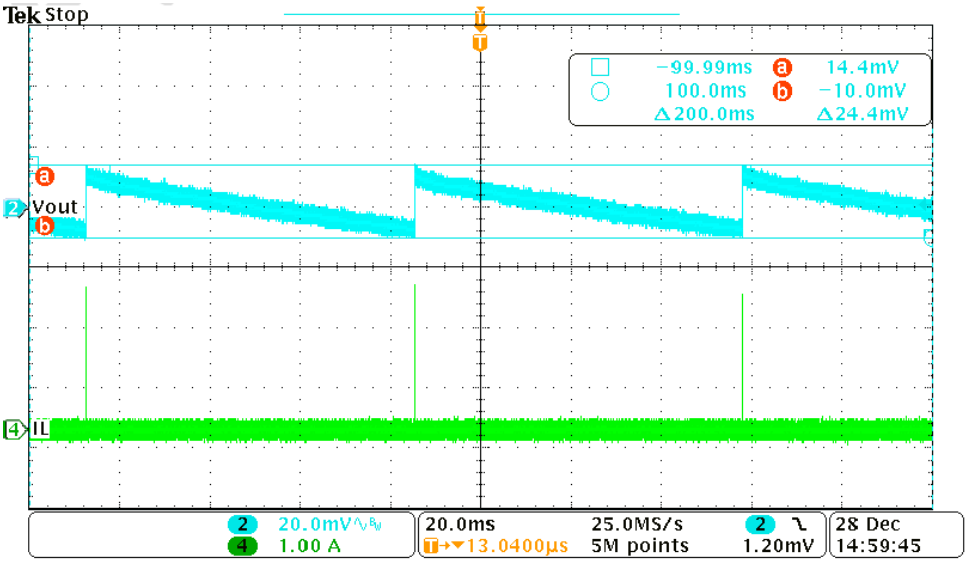


Figure 14. Output Ripple with 0 A Loading at ECO Mode

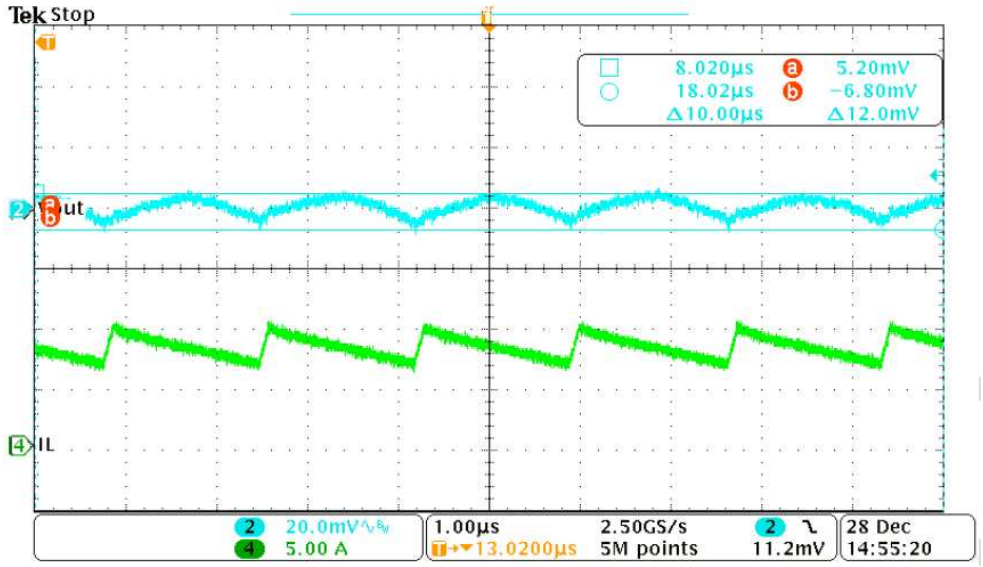


Figure 15. Output Ripple with 8 A Loading at ECO Mode

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Figure 16 and Figure 17 show the output voltage ripple with 0-A loading at OOA mode and FCCM mode. Input voltage is 12 V.

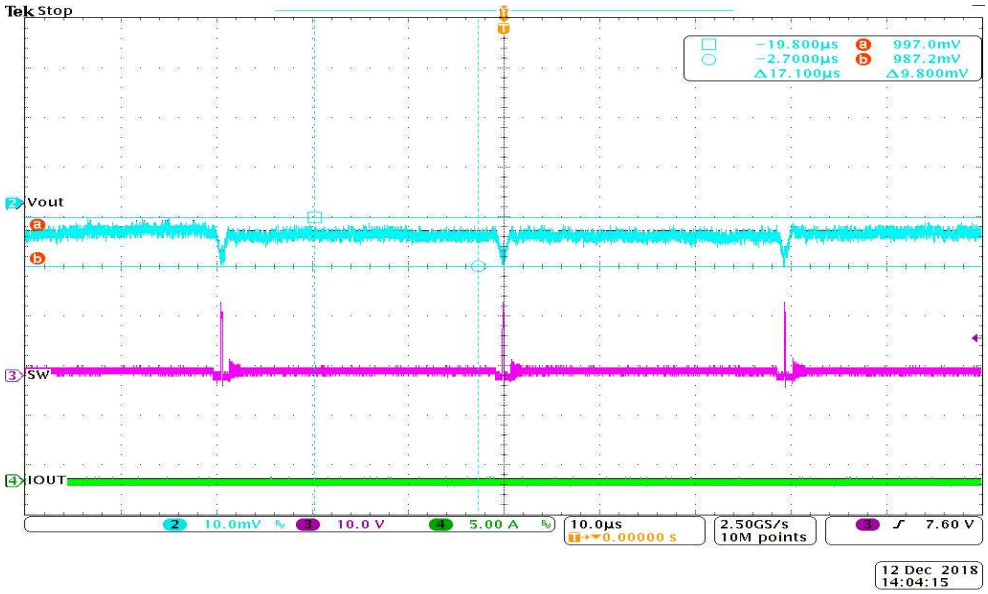


Figure 16. Output Ripple with 0 A at OOA Mode

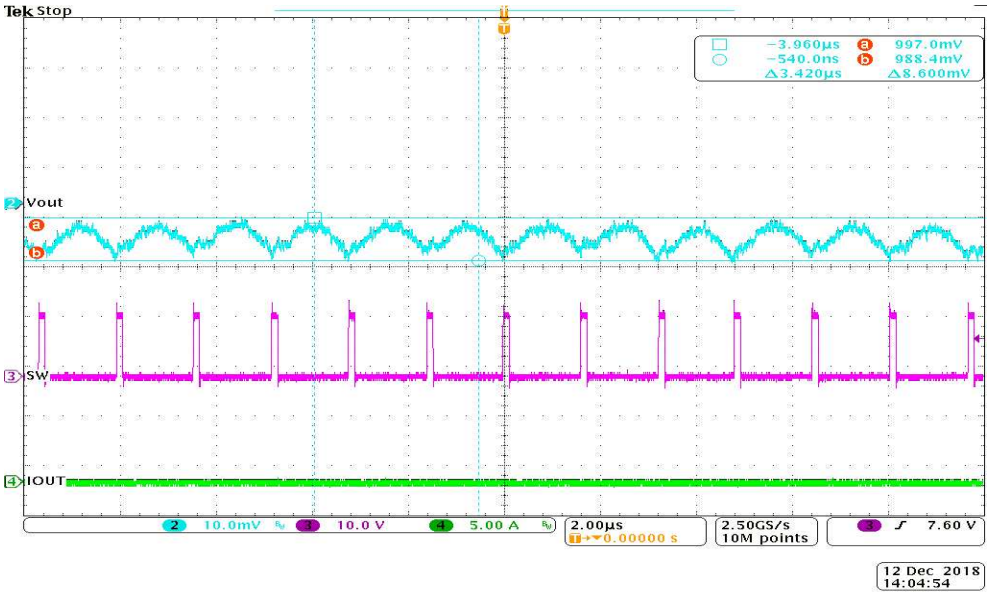


Figure 17. Output Ripple with 0 A at FCCM Mode

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6.4 Load Transient

Below figures show TPS568230 response to load transient at 12-V input and 1.05-V output. In Figure 18, the current step is from 0.8 A to 7.2 A and the current step slew rate is 2.5 A/µs. In Figure 19, the current load is from 2 A to 6 A.

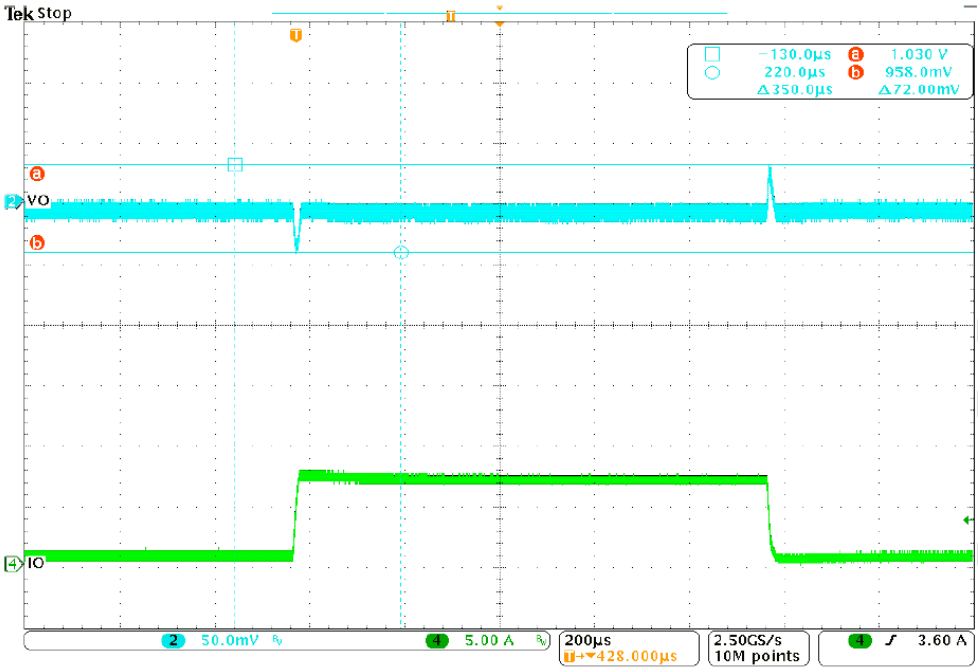


Figure 18. Load Transient from 0.8 A to 7.2 A

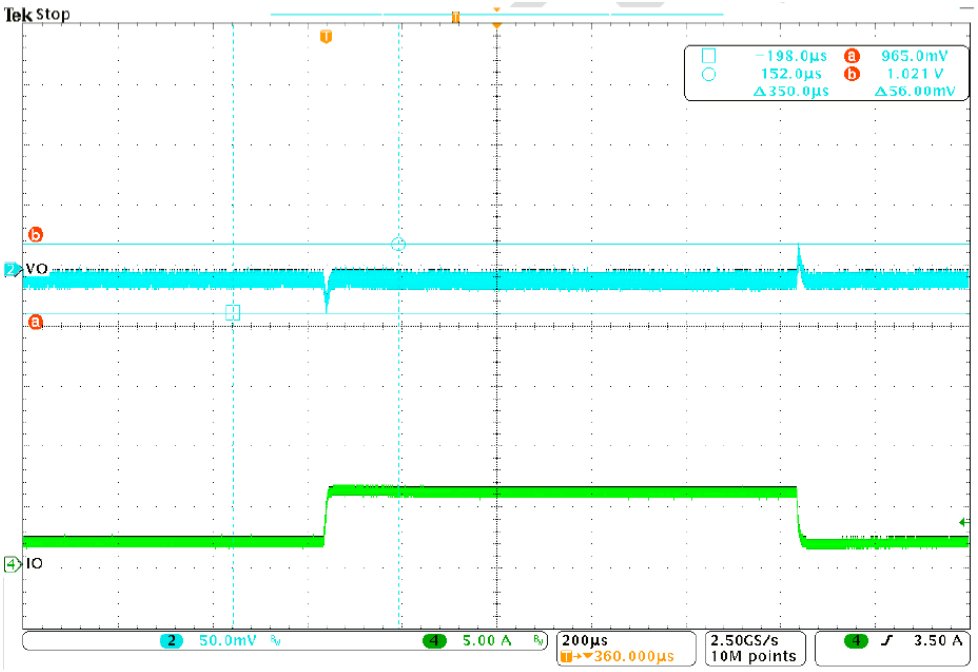


Figure 19. Load Transient from 2 A to 6 A

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6.5 Thermal

The thermal image in Figure 20 shows the EVM with 12-V input, 1.05-V output and full loading of 8 A at room temperature.

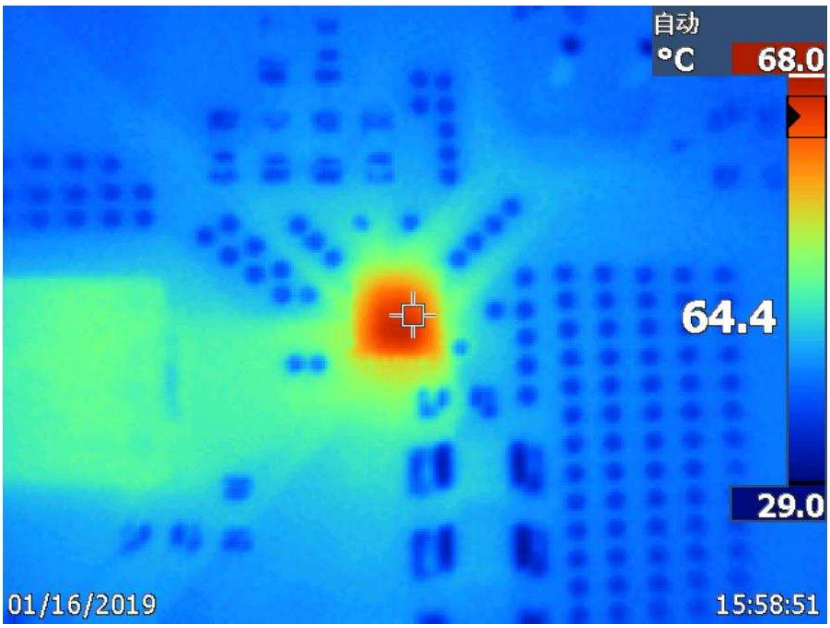


Figure 20. Thermal

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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.

【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。

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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
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。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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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