LM60440AQEVM User's Guide

The Texas Instruments LM60440AQEVM evaluation module helps designers evaluate the operation and performance of the LM60440-Q1 wide-input buck converters. The LM60440-Q1 is an easy-to-use synchronous step-down DC/DC converter capable of driving up to 4.0 A of load current from an input voltage of up to 36 V. The LM60440AQEVM features an adjustable output voltage of 5 V and a switching frequency of 400 kHz. See the *LMR60440-Q1 3.8-V to 36-V, 4-A Synchronous Step-down Voltage Converter Data Sheet* data sheets for additional features, detailed descriptions, and available options.

Table 1. Device and Package Configurations

EVM	U1	FREQUENCY	CURRENT
LM60440AQEVM	LM60440AQRPKRQ1	400 kHz	4.0 A

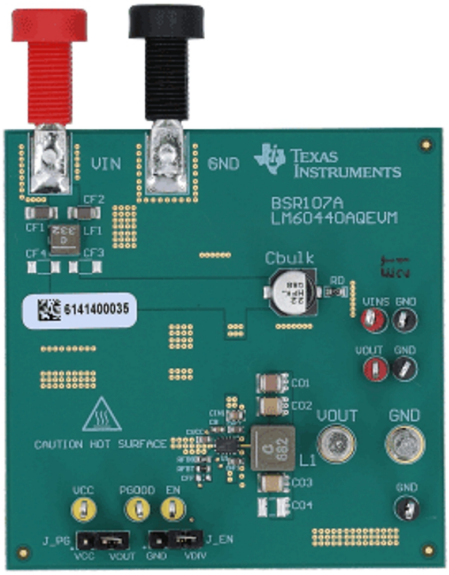


Figure 1. LM60440AQEVM Board

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1 Setup

This section describes the test points and connectors on the EVM and how to properly connect, set up, and use the LM60440AQEVM.

1.1 Test Points

The test points on the top of the board can be used for connecting to the input and output of the EVM. See Figure 2 for typical test setup. The functions of the test points connections are:

- **VIN --** Input supply to EVM including an EMI filter. Connect to a suitable input supply. Connect at this point for conducted EMI test.
- **VINS --** Input voltage sense to the IC. Connect to a DMM to measure input voltage after EMI filter.
- **VOUT --** Output voltage of EVM. Connect to a desired load.
- **VOUTS --** Output voltage sense test point. This test point is a direct short to VOUT. Connecte to a DMM to measure the output voltage.
- **GND --** Ground connections for the input supply, desired load, or test points.
- **VCC --** This test point is connected to the VCC pin. Connect to a DMM to monitor VCC regulation.
- **EN --**This test point is connected to the EN pin. By default, a resistor divider (REN1 and REN2) from VIN is used to enable the IC.
- **PGOOD --** This test point is connected to the PGOOD pin from the IC. It is an open-drain output of the PGOOD pin. Can be tied to external supply through a pullup resistor or left open.

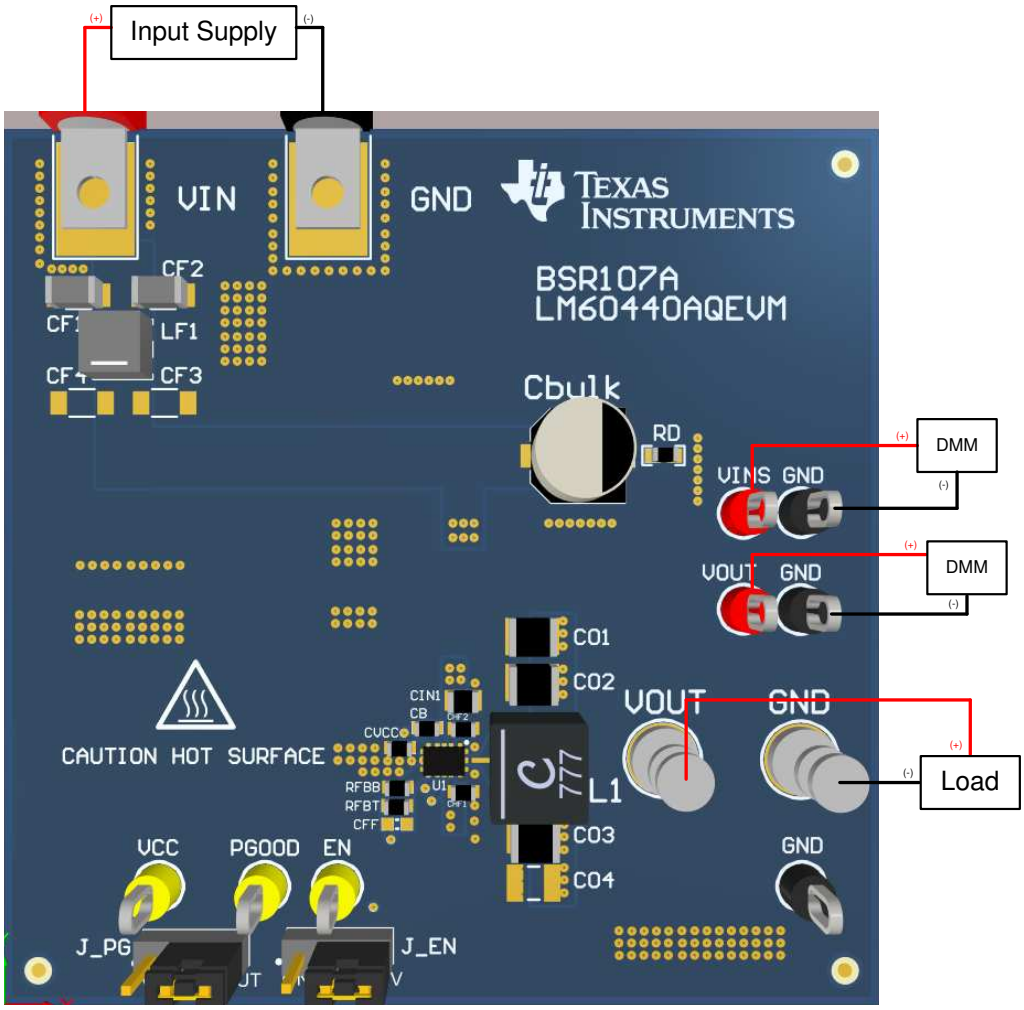


Figure 2. EVM Board Connections

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1.2 Jumpers and Test Points

See Figure 3 for jumper locations.

- **J_EN -** This jumper allows the ENABLE input to be connected to GND in order to disable the IC. By default, a resistor divider (REN1 and REN2) from VIN is used to enable the IC.
- **J_PG -** Use this jumper to select how the PGOOD pin can be connected. By default, a jumper connects the pin with a pullup resistor to the output voltage.



Figure 3. Jumper Locations

2 Operation

2.1 Quick Start

1. Connect the voltage supply between VIN and GND banana jacks inputs.
2. Connect the load between VOUT and GND test points.
3. Set the supply voltage at an appropriate level between 4.8 V to 36 V. Set the current limit of the supply to an appropriate level.
4. Turn on the power supply. With the default configuration, the EVM powers up and provides V_{OUT} = 5 V.
5. Monitor the output voltage. The maximum load current must be 4.0 A with the LM60440-Q1 device.

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3 Schematic

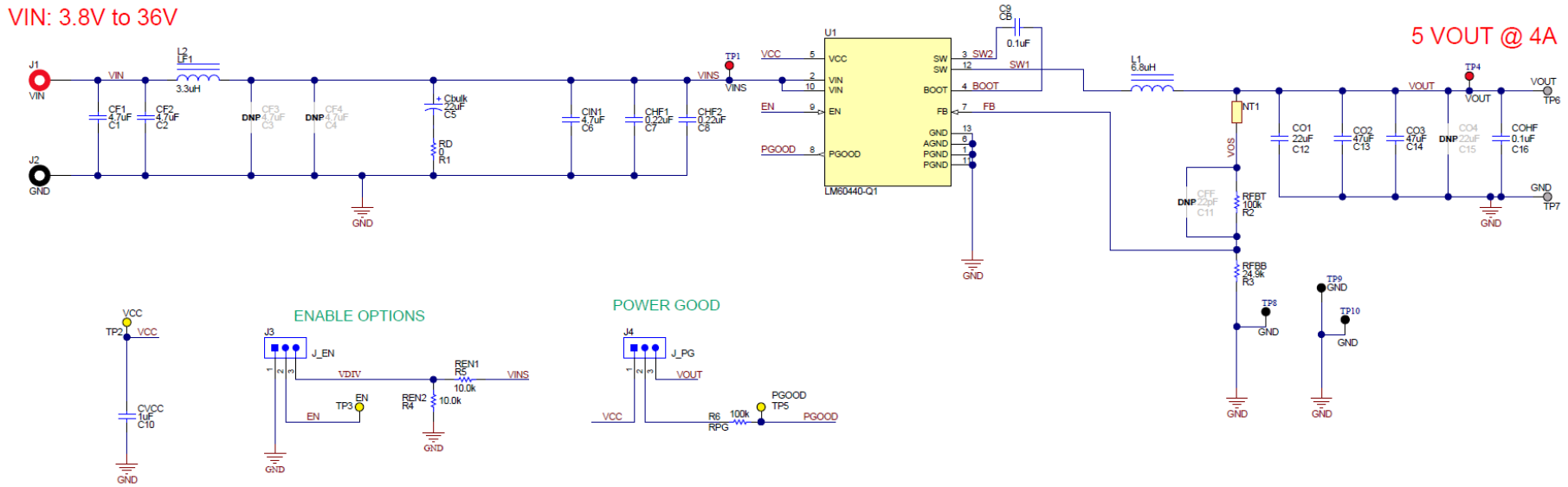


Figure 4. LM60440AQEVM Schematic

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4 Board Layout

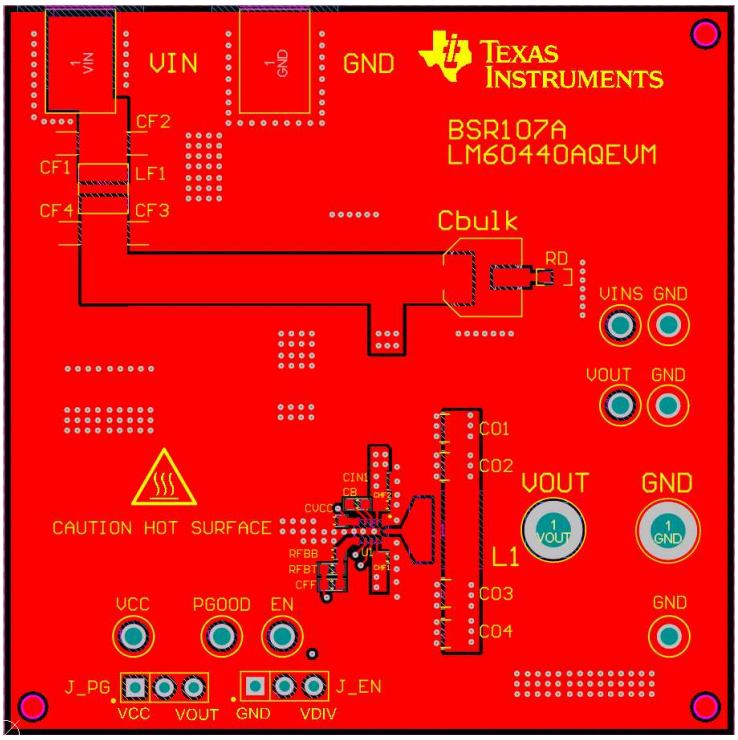


Figure 5. Top View of EVM

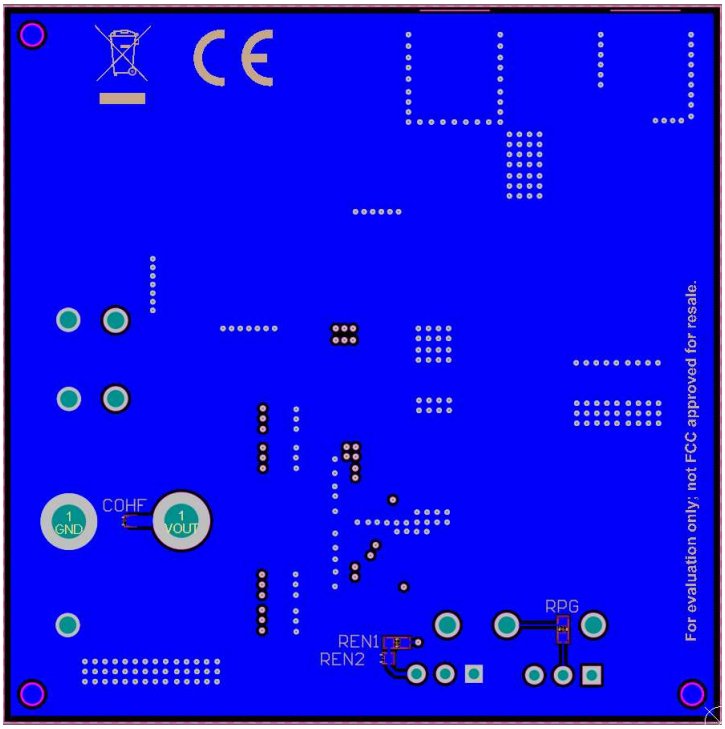


Figure 6. Bottom View of EVM

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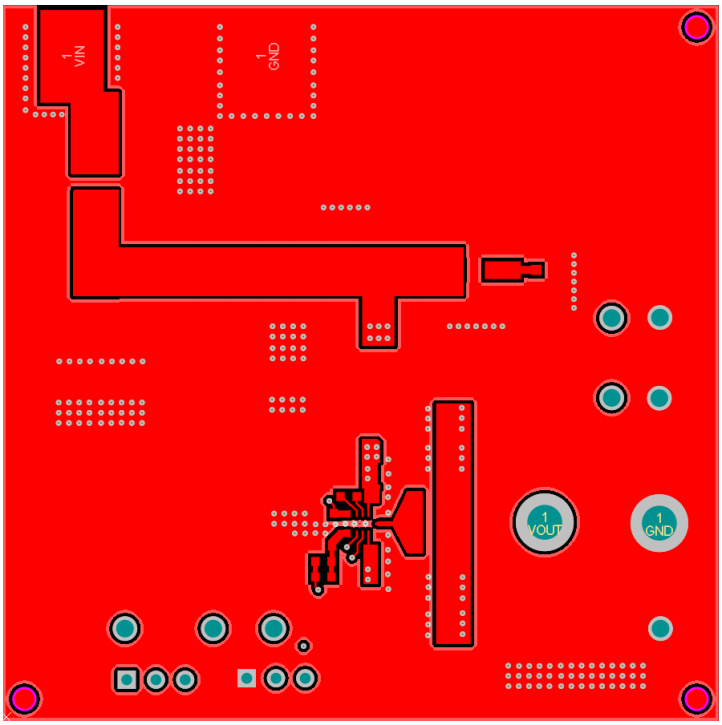


Figure 7. EVM Top Copper Layer

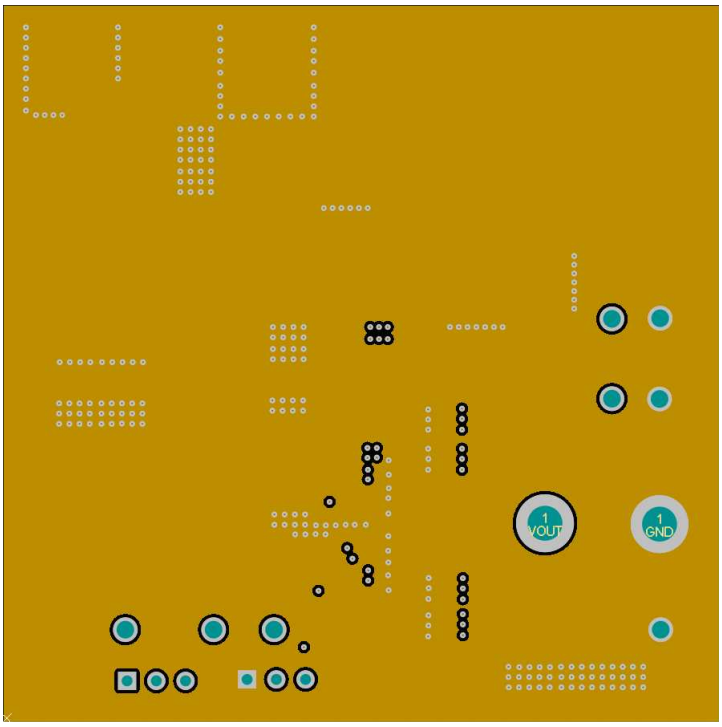


Figure 8. EVM Mid Layer One

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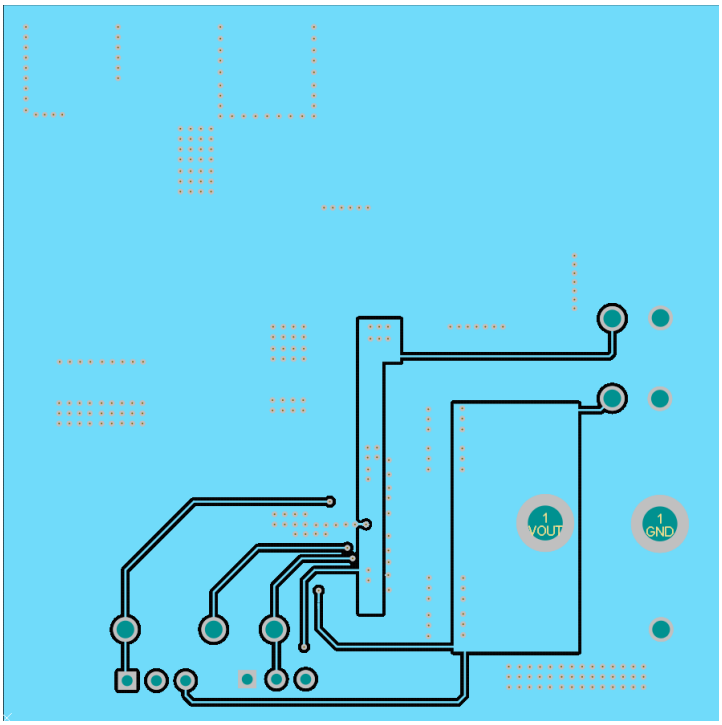


Figure 9. EVM Mid Layer Two

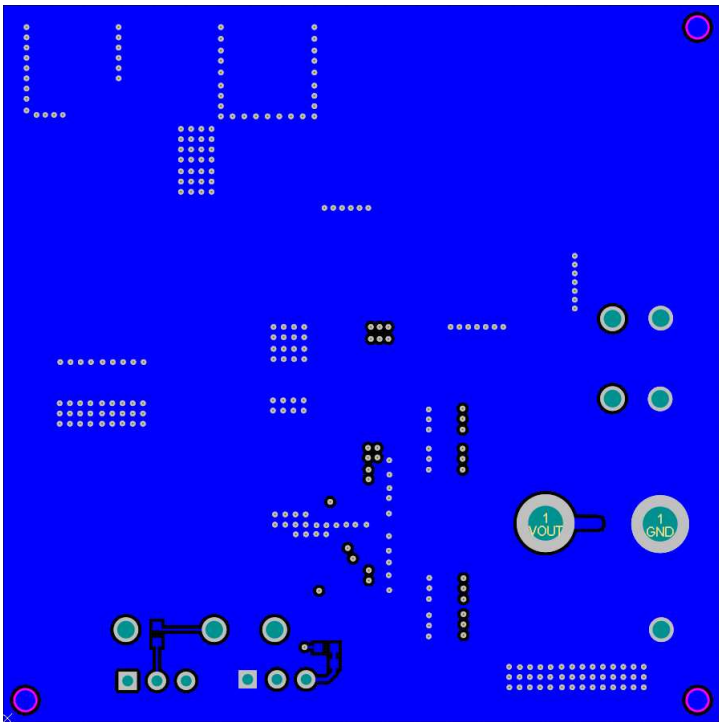


Figure 10. EVM Bottom Copper Layer

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5 Bill of Materials

Table 2. Bill of Materials

DESIGNATOR	COMMENT	DESCRIPTION	PART NUMBER	MANUFACTURER	QUANTITY
C1, C2	CF1, CF2	CAP, CERM, 4.7 µF, 50 V, ±10%, X7R, 1206	GRM31CR71H475KA12L	MuRata	2
C5	Cbulk	CAP, AL, 22 µF, 50 V, ±20%, 0.88 Ω, AEC-Q200 Grade 2, SMD	EEE-FK1H220P	Panasonic	1
C6	CIN1	CAP, CERM, 4.7 µF, 50 V, ±10%, X5R, 0805	C2012X5R1H475K125AB	TDK	1
C7, C8	CHF1, CHF2	CAP, CERM, 0.22 µF, 50 V, ±10%, X7R, 0603	C1608X7R1H224K080AB	TDK	2
C9, C16	CB, COHF	CAP, CERM, 0.1 µF, 25 V, ±10%, X7R, 0603	06033C104KAT2A	AVX	2
C10	CVCC	CAP, CERM, 1 µF, 25 V, ±10%, X7R, 0603	885012206076	Wurth Elektronik	1
C12	CO1	CAP, CERM, 22 µF, 25 V, ±10%, X5R, 1210	CL32A226KAJNNNE	Samsung Electro-Mechanics	1
C13, C14	CO2, CO3	CAP, CERM, 47 µF, 16 V, ±10%, X5R, 1210	GRM32ER61C476KE15L	MuRata	2
J1	VIN	Standard Banana Jack, Insulated, Red	6091	Keystone	1
J2	VOUT	Standard Banana Jack, Insulated, Black	6092	Keystone	1
J3, J4	J_EN, J_PG	Header, 100 mil, 3x1, Gold, TH	HTSW-103-07-G-S	Samtec	2
L1	L1	Inductor, Shielded, Composite, 6.8 µH, 9 A, 0.0208 Ω, AEC-Q200 Grade 1, SMD	XAL6060-682MEB	Coilcraft	1
L2	LF1	Inductor, Shielded, Composite, 3.3 µH, 5.5 A, 0.026 Ω, SMD	XAL4030-332MEB	Coilcraft	1
R1	RD	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00	Stackpole Electronics Inc	1
R2	RFBT	RES, 100 k, 1%, 0.1 W, 0603	RC0603FR-07100KL	Yageo	1
R3	RFBB	RES, 24.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060324K9FKEA	Vishay-Dale	1
R4, R5	REN1, REN2	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K0FKEA	Vishay-Dale	2
R6	RPG	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603100KFKEA	Vishay-Dale	1
SH-J1, SH-J2	SNT-100-BK-G	Shunt, 100 mil, Gold plated, Black	SNT-100-BK-G	Samtec	2

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Table 2. Bill of Materials (continued)

DESIGNATOR	COMMENT	DESCRIPTION	PART NUMBER	MANUFACTURER	QUANTITY
TP1, TP4	VINS, VOUTS	Test Point, Multipurpose, Red, TH	5010	Keystone	2
TP2, TP3, TP5	VCC, EN, PGOOD	Test Point, Multipurpose, Yellow, TH	5014	Keystone	3
TP6, TP7	VOUT, GND	Terminal, Turret, TH, Double	1503-2	Keystone	2
TP8, TP9, TP10	GND	Test Point, Multipurpose, Black, TH	5011	Keystone	3
U1	LM60440AQRPKRQ1	LM60440-Q1, RPK0013A (VQFN-12)	LM60440AQRPKRQ1	Texas Instruments	1
C3, C4	CF3, CF4	CAP, CERM, 4.7 µF, 50 V, ±10%, X7R, 1206	GRM31CR71H475KA12L	MuRata	0
C11	CFF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, 0603	GRM1885C1H220JA01D	MuRata	0
C15	CO4	CAP, CERM, 22 µF, 25 V, ±10%, X5R, 1210	CL32A226KAJNNNE	Samsung Electro-Mechanics	0
FID1, FID2, FID3, FID4, FID5, FID6	Fiducial	Fiducial mark. There is nothing to buy or mount.	N/A	N/A	0

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6 Test Results (Preliminary)

Section 6.1 details the test results from the LM60440AQEVM variant.

6.1 LM60440AQEVM Test Results

The LM60440AQEVM variant is used for all figures from Figure 12 to Figure 20.

6.1.1 Efficiency and Load Regulation

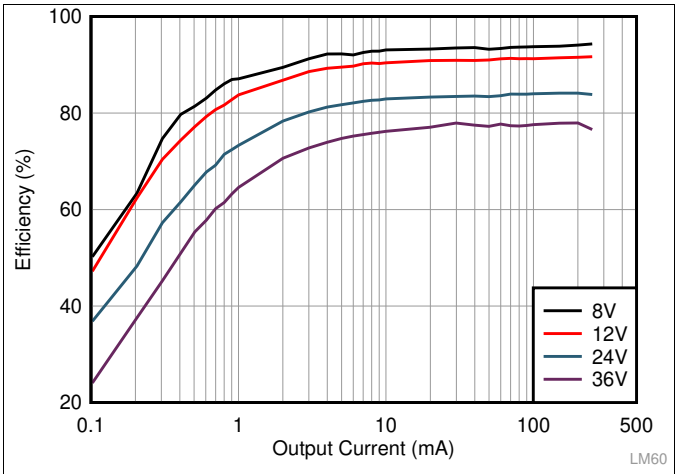


Figure 11. LM60440AQEVM 5 V_{OUT} Low Load Efficiency

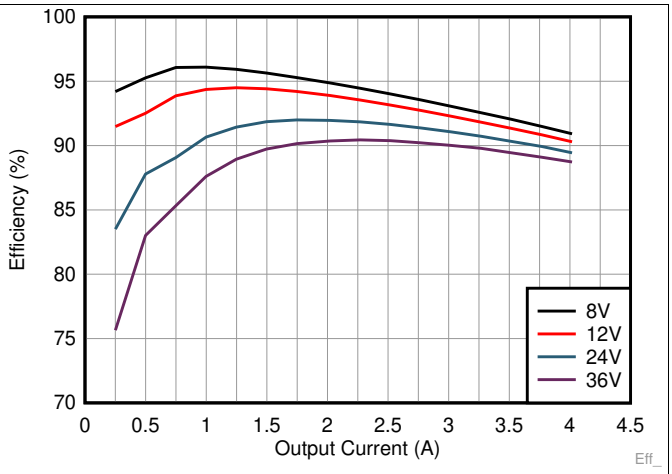


Figure 12. LM60440AQEVM 5 V_{OUT} High Load Efficiency

6.1.2 Start-up and Load Regulation

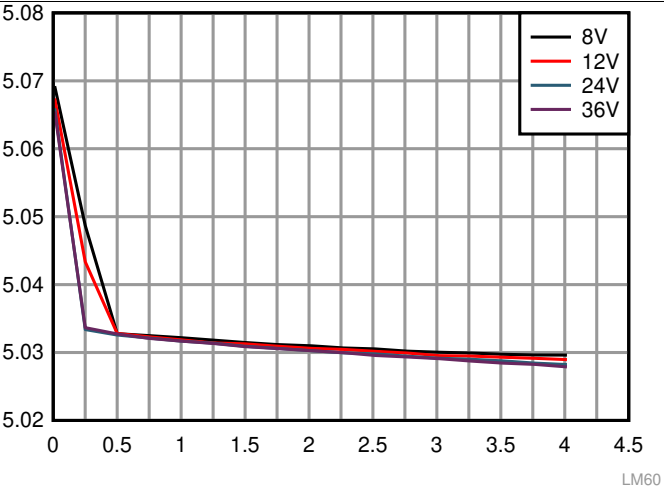


Figure 13. LM60440AQEVM 5 V_{OUT} Load Regulation

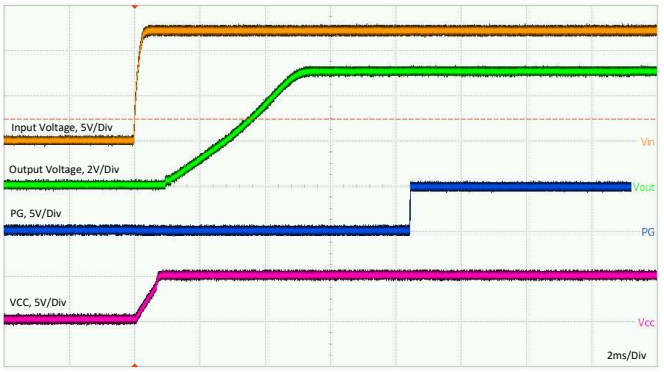


Figure 14. LM60440AQEVM 5 V_{OUT}, 4 A Load Start-up

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6.1.3 Load Transients

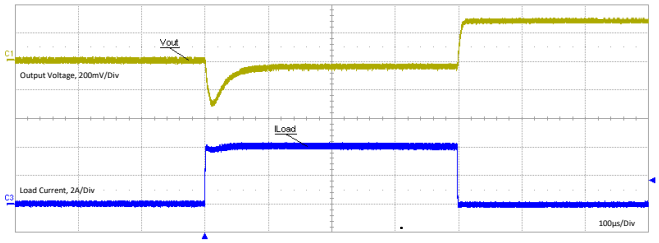


Figure 15. LM60440AQEVM Load Transient
12 V_{IN}, 5 V_{OUT}, I_{OUT} = 0 A to 4 A, T_R = T_F = 4 µs
CH1 = VOUT, CH3 = IOUT

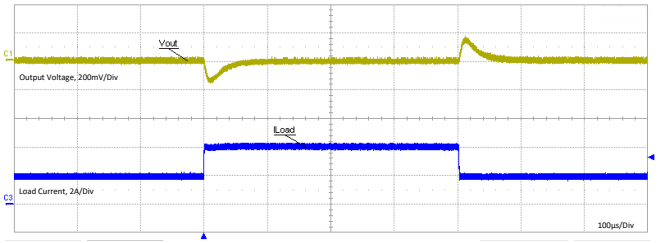


Figure 16. LM60440AQEVM Load Transient
12 V_{IN}, 5 V_{OUT}, I_{OUT} = 0 A to 2 A, T_R = T_F = 2 µs
CH1 = VOUT, CH3 = IOUT

6.1.4 Thermal Picture

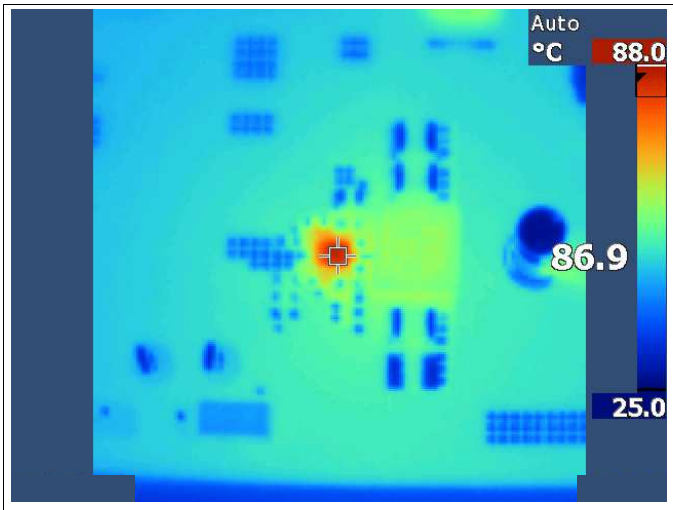


Figure 17. LM60440AQEVM 5 V_{OUT} Thermal Capture,
12 V_{IN}, 4 A Load, 400 kHz

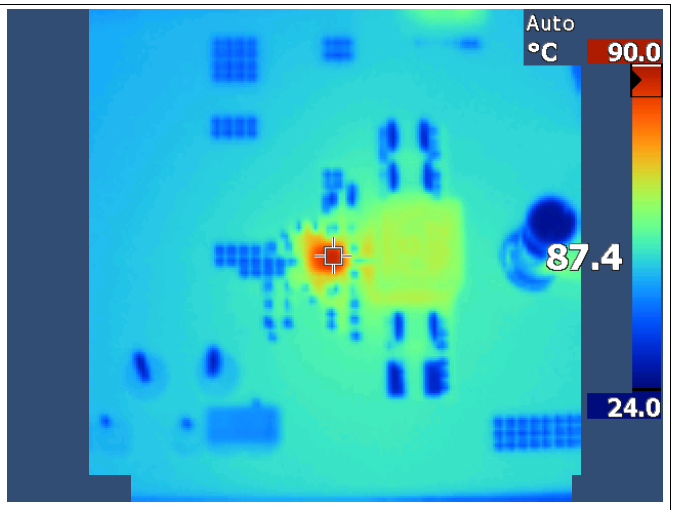


Figure 18. LM60440AQEVM 5 V_{OUT} Thermal Capture,
24 V_{IN}, 4 A Load, 400 kHz

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6.1.5 Conducted EMI

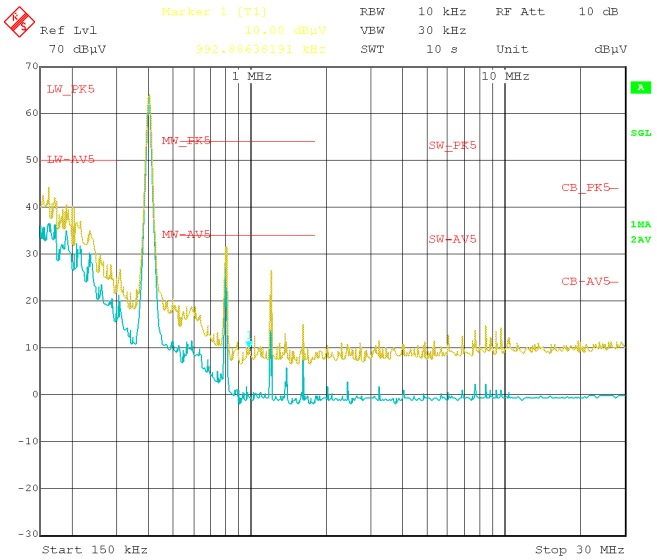


Figure 19. LM60440AQEVM Low Frequency Conducted EMI Results
13.5 V_{IN}, 5 V_{OUT}, I_{OUT}= 4 A
(Blue-Average and Yellow-Peak)

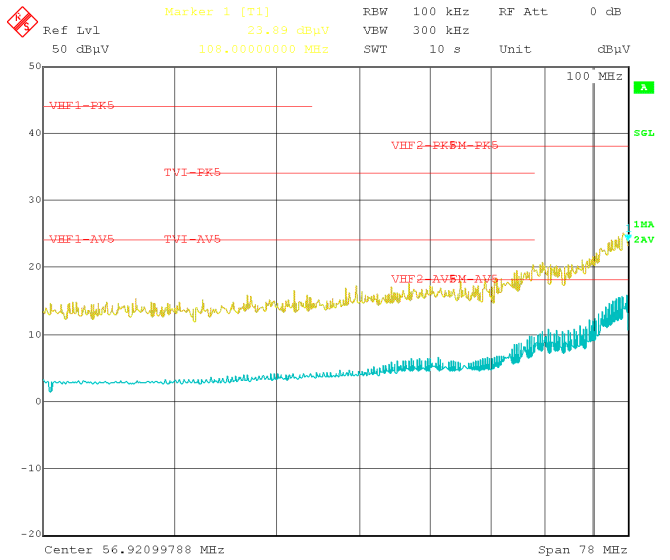


Figure 20. LM60440AQEVM High Frequency Conducted EMI Results
13.5 V_{IN}, 5 V_{OUT}, I_{OUT}= 4 A
(Blue-Average and Yellow-Peak)

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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.

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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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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.

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