User's Guide

LM61460-Q1 EVM User's Guide

ABSTRACT

The LM61460-Q1 evaluation module (EVM) is designed to help customers evaluate the performance of the LM61460-Q1 synchronous step-down voltage converter. This EVM implements the LM61460-Q1 in a 14-pin wettable flanks Hotrod™ package, as shown in Table 1-1. It is capable of delivering 5-V output voltage and up to 6-A load current with exceptional efficiency and output accuracy in a very small solution size. The EVM provides multiple power connectors and test points. It also provides a good layout example, which is optimized for EMI and thermal performance.

Table 1-1. Device and Package Configurations

CONVERTER	IC	PACKAGE
U1	LM61460-Q1	14-pin wettable flanks Hotrod package 4.0 mm × 3.5 mm × 1.0 mm

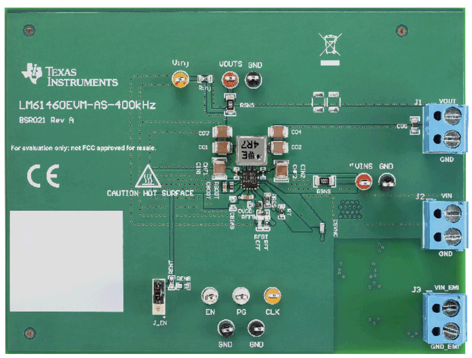

Figure 1-1. LM61460EVM Front

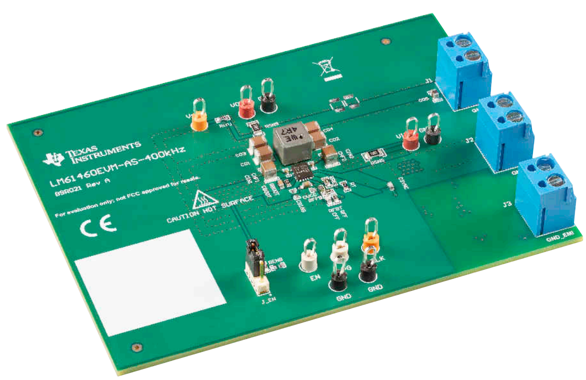

Figure 1-2. LM61460EVM Angle

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Trademarks

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1 Introduction

1.1 LM61460 Synchronous Step-Down Voltage Converter

The LM61460-Q1 device is an easy-to-use synchronous step-down DC/DC converter capable of driving up to 6 A of load current from a supply voltage ranging from 3 V to 36 V. The LM61460-Q1 provides exceptional efficiency and output accuracy in a very small solution size. The LM61460-Q1 is capable of delivering 6 A of load current and is peak current limit controlled. The following are additional features that provide both flexible and easy-to-use solutions for a wide range of applications:

- Adjustable switching frequency
- Synchronization to an external clock
- FPWM variant (LM61460AFS)
- Power-good flag
- Precision enable

Automatic frequency foldback at light load and optional external bias improve efficiency over the entire load range. The device requires few external components and has a pinout designed for optimal EMI and thermal performance. Protection features include the following:

- Thermal shutdown
- Input undervoltage lockout
- Cycle-by-cycle current limiting
- Hiccup short-circuit protection

The LM61460-Q1 device is pin-to-pin compatible with the LM61440-Q1 for easy output current scaling.

For a quick reference, Figure 1-1 shows the pin configuration of the LM61460-Q1 and Figure 1-2 shows the simplified schematic. See the *LM61460-Q1 Automotive 3-V to 36-V, 6-A, Low-Noise Synchronous Step-Down Converter Data Sheet* for more detailed feature descriptions and design guide.

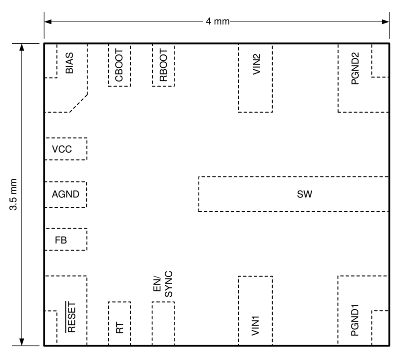

Figure 1-1. LM61460-Q1 Pin Configuration (Top View)

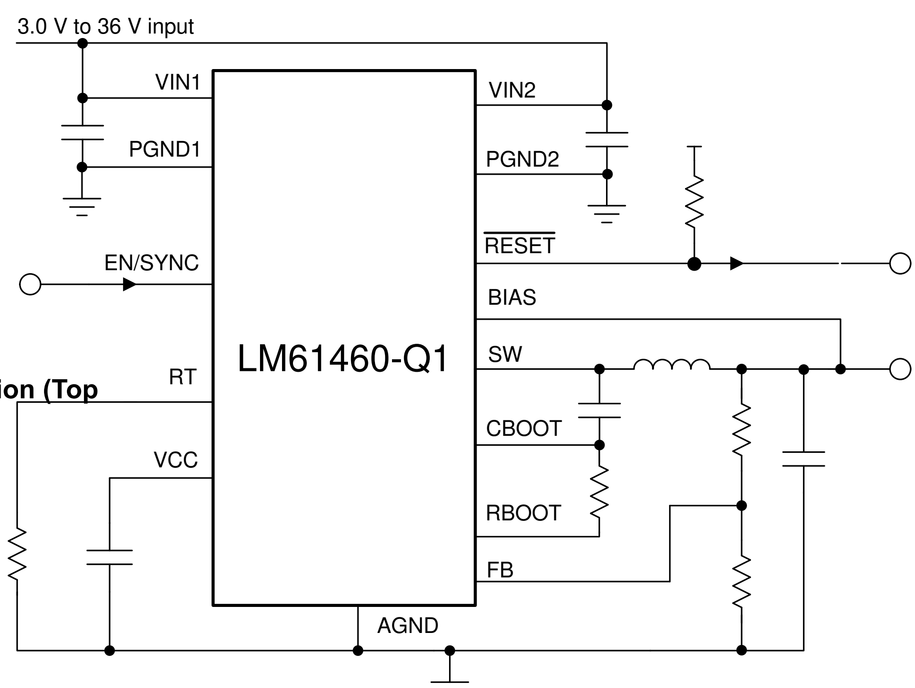

Figure 1-2. LM61460-Q1 Schematic

1.2 LM61460-Q1 Evaluation Module

The LM61460-Q1 EVM has the board populated with the LM61460 in either one of two variants. Based on the label populated, you can figure out which device trim is populated on the EVM and the corresponding features. This board uses the LM61460-Q1 and limiting current to 6 A and comes with auto mode enabled.

Table 1-1. EVM Variants

LABEL	U1	I_{OUT}	SWITCHING FREQUENCY	V_{IN} RANGE	V_{OUT}	AUTO MODE	FPWM	SPREAD SPECTRUM
LM61460EVM -AS-400K	LM61460AAS QRJRRQ1	6 A	400 kHz	3 to 36 V	5 V	Enabled	Disabled	Enabled
LM61460EVM -FS-400K	LM61460AFS QRJRRQ1	6 A	400 kHz	3 to 36 V	5 V	Disabled	Enabled	Enabled

2 Quick Start

1. Connect the voltage supply between the VIN and GND connectors or between VIN_EMI and GND_EMI to include the on-board input filter in the input path. Use short and thick gauge wires to minimize inductance and IR drop. Note that sense points for V_{IN} and V_{OUT} are provided.
2. Connect the load of the converter between VOUT and GND connectors using short and thick wires.
3. Set the supply voltage at an appropriate level between 6 V to 36 V. The 6 V minimum ensures enough head room for V_{OUT} to equal 5 V at a 6 A load current. Set the current limit of the supply to an appropriate level to supply needed current and protection.
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 with sense points. The maximum load current must be 6 A with the LM61460-Q1. Note that the maximum output current may need to derate if ambient temperature is high, especially if device is operated at higher frequency, for example, 2.2MHz.

See Figure 2-1 for connector locations.

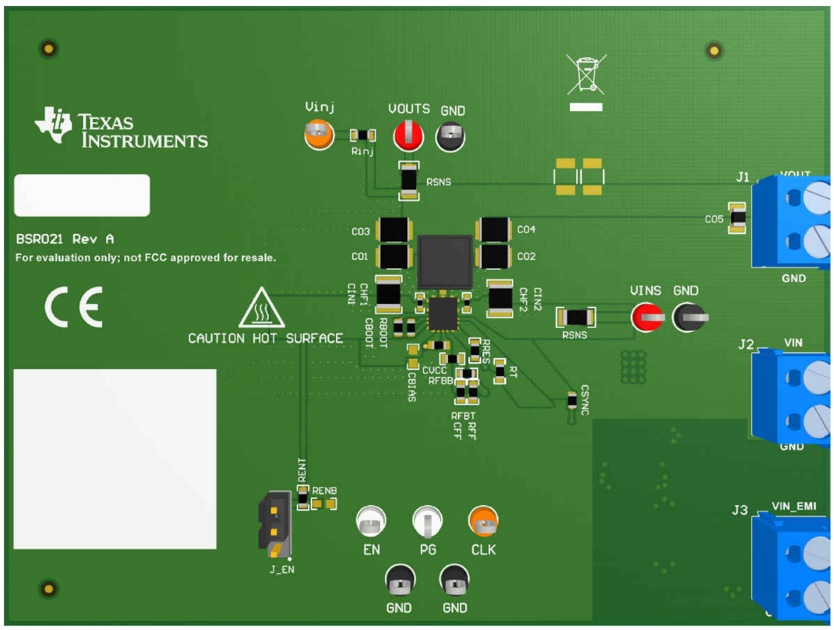

Figure 2-1. Top View of LM61460-Q1 EVM

CAUTION

Caution Hot surface.
Contact may cause burns.
Do not touch.

3 Detailed Descriptions

This section describes the connectors on the EVM and how to properly connect, set up, and use the EVM. See Figure 2-1 for a top view of the EVM.

VOUT Output voltage of the converter

VOUT connectors connect to the power inductor and output capacitors. Connect the load between VOUT connector and the GND connector right next to it to provide load current. Connect the loading device to the board with short and thick wires to handle the large DC output current.

GND Ground of the converter

The GND is connected to the PGND and AGND pins of the device, as well as the ground of the input and output capacitors. The GND connections next to VIN, VIN_EMI, and VOUT connectors are meant for current return path for the supply voltage and load, respectively. Connectors are provided in pairs to allow easy and accurate sensing of voltages. Connect to supply and load grounds with short and thick wires. Other GND connectors are for signal measurement and probing.

V_{IN} Input voltage to the converter

The V_{IN} connector connects to the input capacitors and the VIN pins of the LM61460-Q1. Connect the supply voltage from a power supply or a battery between VIN and GND connectors as power input to the device. The voltage range must be higher than 3.9 V for the device to start up. V_{IN} higher than 6 V provides regulated 5 V output voltage. V_{IN} must be no higher than 36 V to avoid damaging the device. After start-up, the device stays active until V_{IN} drops below 3 V. The current limit on the supply must be high enough to provide the needed supply current. Otherwise, the supply voltage does not maintain the desired voltage. The supply voltage must be connected to the board with short and thick wires to handle the pulsing input current. If long cables are used to power up the board, damping must be provided by added CFLT3 and RFLT3 to avoid oscillation between the cable parasitic inductance and the low-ESR ceramic capacitors.

VIN_EMI Input voltage to input filter of the converter

If the input filter is desired between the supply and the LM61460-Q1, connect the supply voltage between VIN_EMI and GND_EMI. The supply voltage must be connected to the board with short and thick wires to handle pulsing input current.

The input filter consists of the following: CF1, CF2, CF3, CF4, CF5, CF6, and L2. CD1, CD2, RD1, and RD2 are provided to allow more options to during filter design. To include the input filter in the power path, connect the supply voltage between the VIN_EMI and GND_EMI connectors. The output of the filter is connected to V_{IN}, which is connected to the V_{IN} pins of the LM61460-Q1 and the input capacitors.

Conducted EMI arises from the normal operation of switching circuits. The ON and OFF actions of the power switches generate large discontinuous currents. The discontinuous currents are present at the input side of buck converters. Voltage ripple generated by discontinuous currents can be conducted to the voltage supply for the buck converter. Without filtering, excessive input voltage ripple can compromise operation of other circuits connected to this source. The input filter helps smooth out the voltage perturbations leading to less noise at the power source.

GND_EMI Ground return for the input filter

This is the current return path for the supply connected to VIN_EMI. It provides a short-loop connection to the input filter capacitors to best filter the conducted noise generated from the PCB. Use VIN_EMI and GND_EMI connection if input filter is used and conducted EMI test is desired.

CLK For synchronization clock input

The CLK input connector is designed for external clock input to the EN/SYNC pin. Switching action of the buck is synchronized to the external clock when it is present. The operation mode changes to forced PWM mode automatically, maintaining a constant switching frequency at light load.

EN To monitor the EN pin or input EN control signal

This test point is used to monitor the voltage on the device EN pin. By default, the EN pin is connected to the mid-point of an enable divider. Note that the lower resistor in this divider, RENB, is not populated.

PG To monitor the PGOOD/RESET pin

The PGOOD flag indicates whether the output voltage is within the regulation band. The PGOOD pin of the device is an open-drain output and it is pulled up to V_{OUT} on this board through a pullup resistor. This flag is high impedance when the output voltage is in regulation.

Vinj To aid when making bode plots

There is a low value resistor, Rinj, between VOUT and this node. This feedback divider of the board is connected to this node as well. Stimulus can be applied between this node and VOUT when taking measurements for bode plots.

VOUTS Kelvin sensing for VOUT

This connector is provided to allow V_{OUT} to be measured more accurately.

VINS Kelvin sensing for VIN

This connector is provided to allow V_{IN} to be measured more accurately.

4 Schematic

The bill of materials from EVM Variants is tabulated in *Section 7*. In addition, Figure 4-1 shows the corresponding schematic.

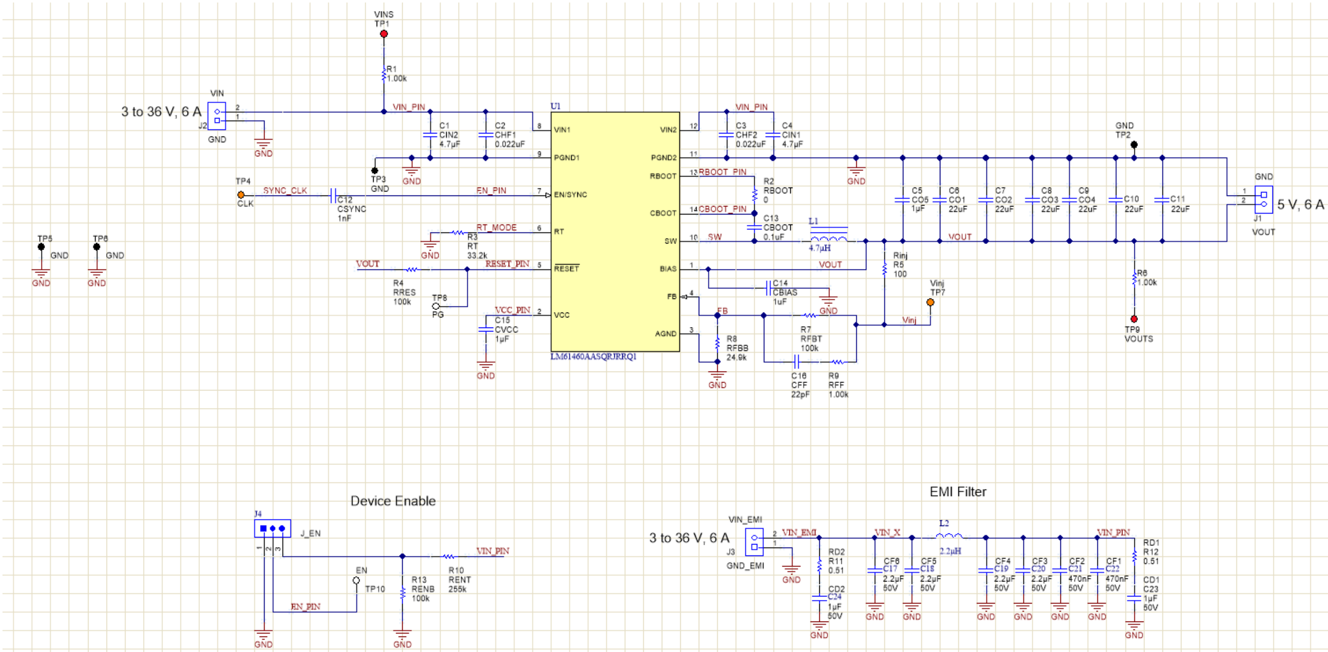

Figure 4-1. LM61460-AS-400K Rev A EVM Schematic

Note

Long leads and additional inductance in used to power the DC/DC may cause issues for ideal device operation. RD2, CD2, RD1, and CD1 are placeholders for damping networks to be populated. For more information regarding this topic, reference the *EMI Filter Components and Their Nonidealities for Automotive DC/DC Regulators Technical Brief*.

4.1 Alternative BOM Configurations

Table 4-1. Different BOM Configurations

VOUT	FREQUENCY	RFBB	RT	COUT	CIN + CHF	L1
3.3 V	400 kHz	43.2 kΩ	33.2 kΩ	6 x 22 µF	2 x 4.7 µF + 2 x 100 nF	4.7 µH (XHMI6060)
3.3 V	2100 kHz	43.2 kΩ	6.04 kΩ	3 x 22 µF	2 x 4.7 µF + 2 x 100 nF	1 µH (XEL5030)
5 V	400 kHz	24.9 kΩ	33.2 kΩ	4 x 22 µF	2 x 4.7 µF + 2 x 100 nF	4.7 µH (XHMI6060)
5 V	2100 kHz	24.9 kΩ	6.04 kΩ	3 x 22 µF	2 x 4.7 µF + 2 x 100 nF	1 µH (XEL5030)

5 Board Layout

Figure 5-1 through Figure 5-6 show the board layout for the LM61460-Q1 EVM. The EVM offers resistors, capacitors, and test points to configure the following:

- Output voltage
- Precision enable pin
- Set frequency
- External clock synchronization

The 14-pin Hotrod package offers a very small size and low-noise solution. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to dissipate heat with an array of thermal vias to connect to all four layers.

Test points have been provided for ease of use to connect the power supply and required load, and to monitor critical signals.

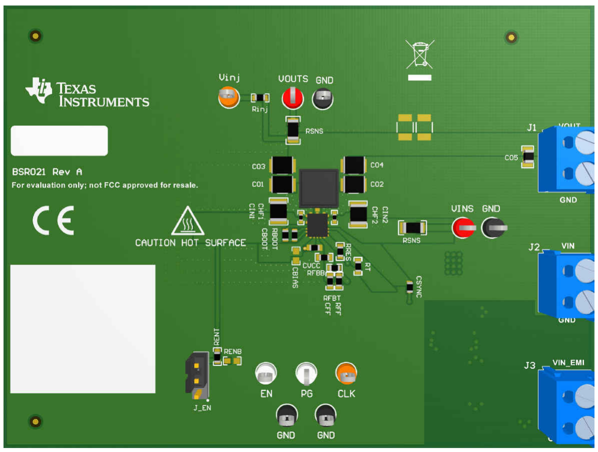

Figure 5-1. Top 3D View

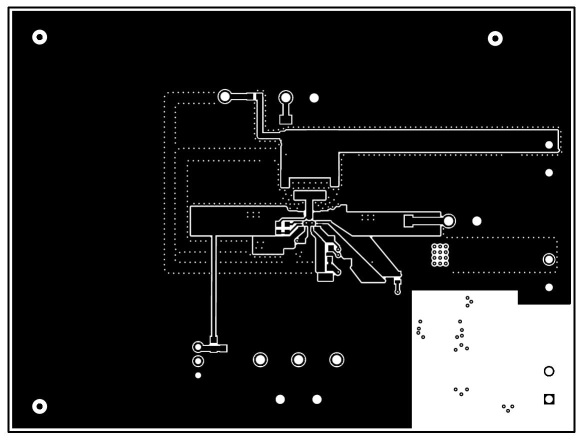

Figure 5-2. Top Layer

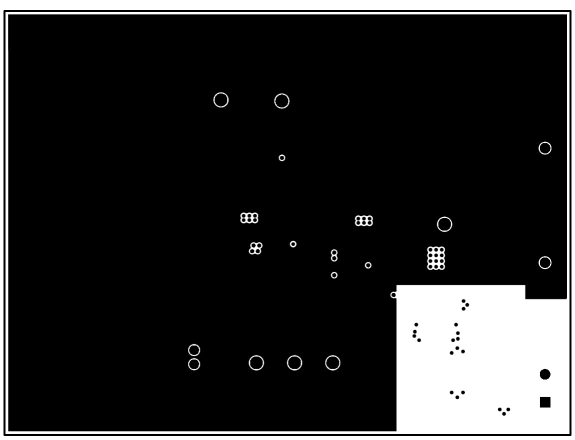

Figure 5-3. Signal Layer 1 - Ground Plane

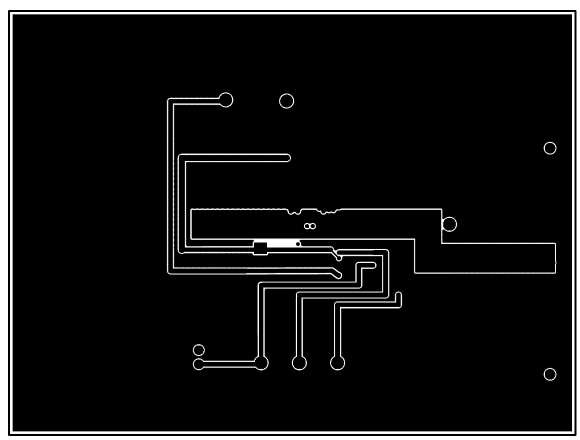

Figure 5-4. Signal Layer 2 - Routing

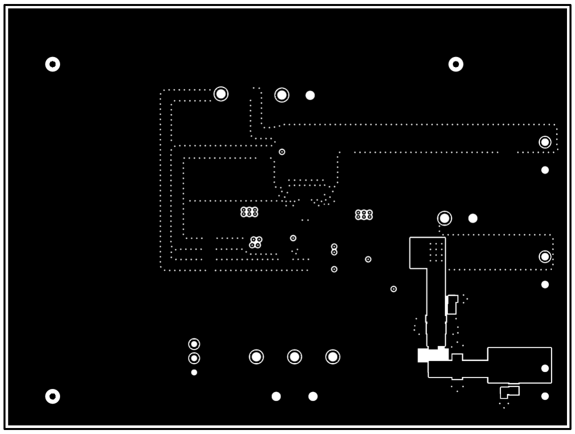

Figure 5-5. Bottom Layer

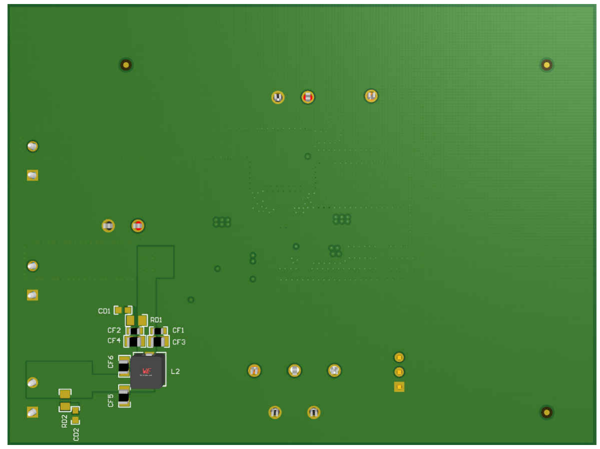

Figure 5-6. Bottom 3D view

6 LM61460EVM Board Test Results

6.1 EMI

The EMI measurements were taken following CISPR 25, Class 5 standards. The measurements were taken at 13.5 VIN, 5 VOUT with a 6 A load.

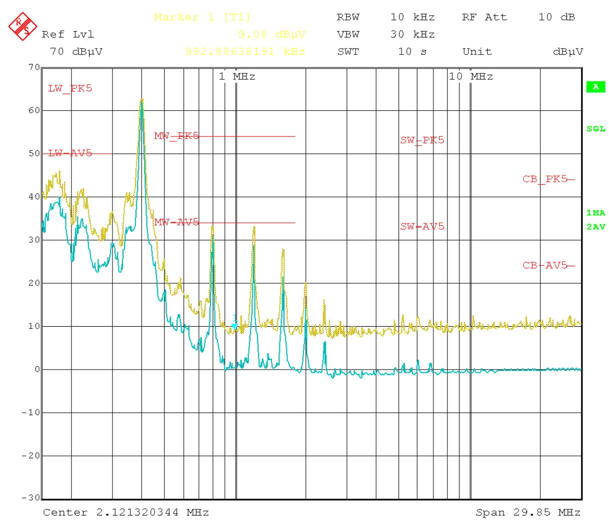

Figure 6-1. Conducted EMI Measurement with CISPR 25 Class 5 Limit Lines (150 kHz to 30 MHz)

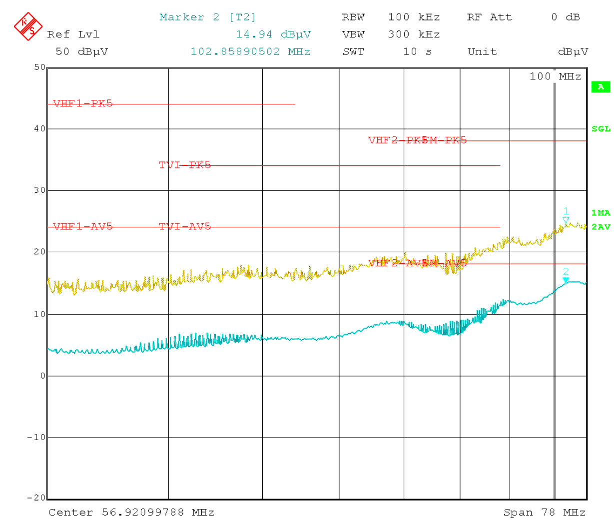

Figure 6-2. Conducted EMI Measurement with CISPR 25 Class 5 Limit Lines (30 MHz to 110 MHz)

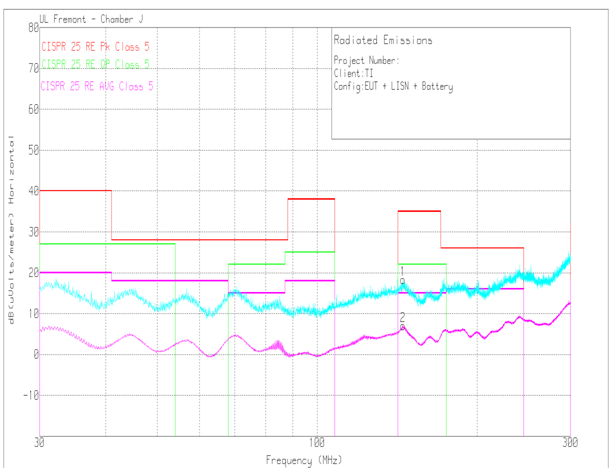

Figure 6-3. Radiated EMI Measurement with Horizontal Bicon Antenna Under CISPR 25 Class 5 Limits

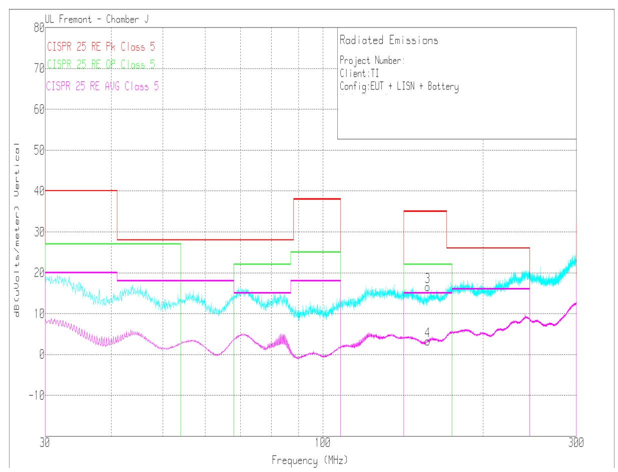

Figure 6-4. Radiated EMI Measurement with Vertical Bicon Antenna Under CISPR 25 Class 5 Limits

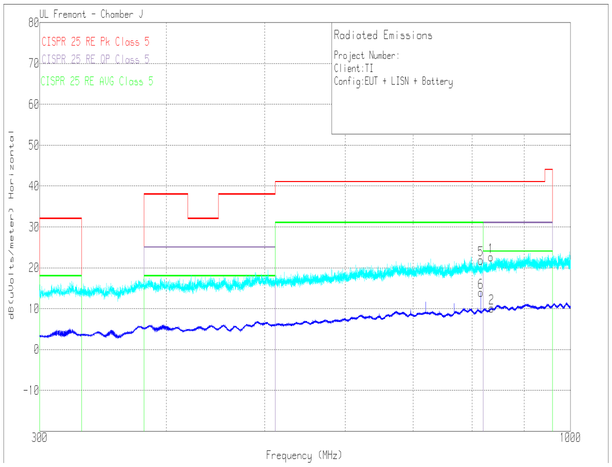

Figure 6-5. Radiated EMI Measurement with Horizontal Log Antenna Under CISPR 25 Class 5 Limits

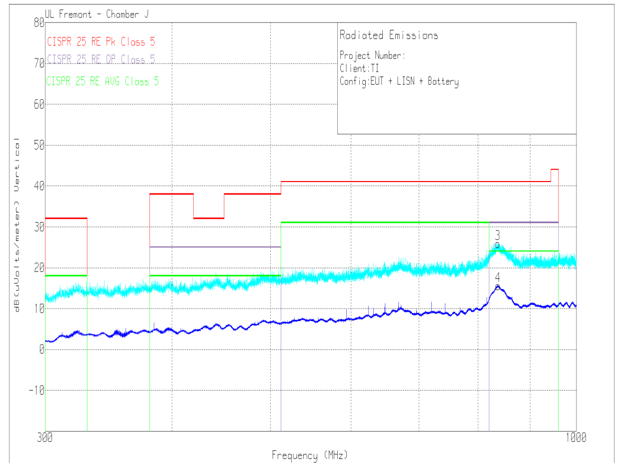

Figure 6-6. Radiated EMI Measurement with Vertical Log Antenna Under CISPR 25 Class 5 Limits

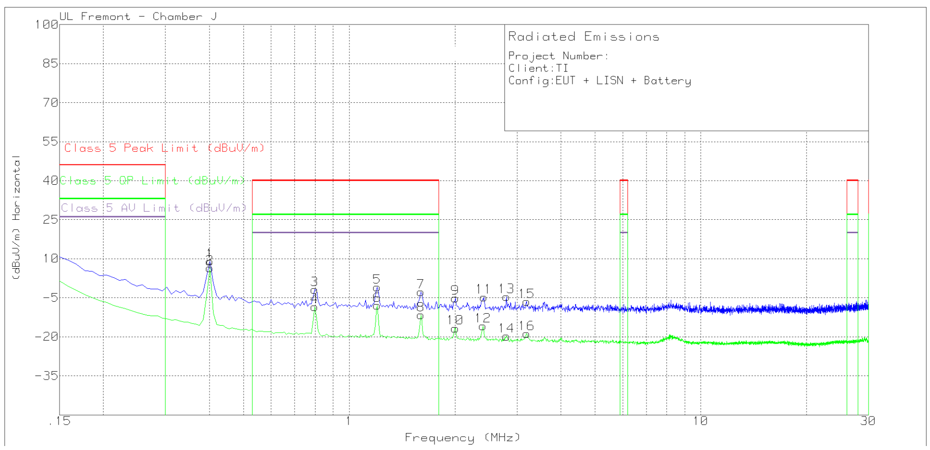

Figure 6-7. Radiated EMI Measurement with Rod Antenna Under CISPR 25 Class 5 Limits

6.2 Board Efficiency

This section provides efficiency plots for the board with LMQ61460AAS populated for Auto mode efficiency and LMQ61460AFS populated for FPWM mode efficiency. For 2.1-MHz data, the output stage has to be changed from the default BOM. The inductor (L1) selected was XEL5030-102MEB.

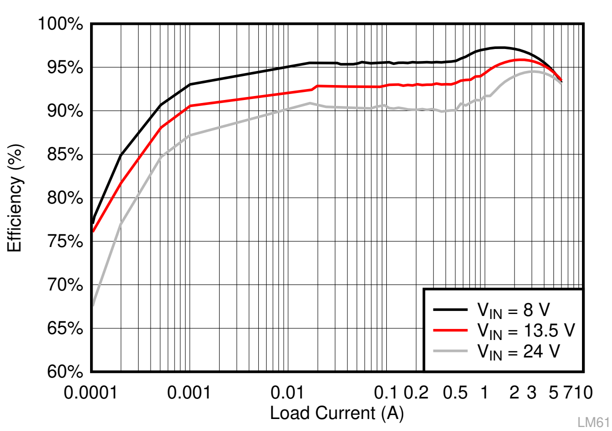

Figure 6-8. F_{SW} = 400 kHz, 5 VOUT, Auto Mode

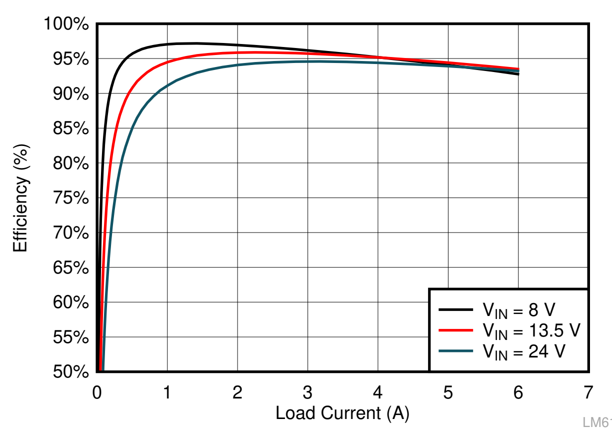

Figure 6-9. F_{SW} = 400 kHz, 5 VOUT, FPWM Mode

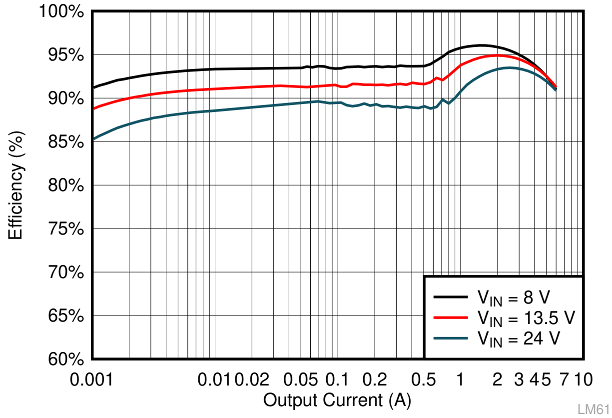

Figure 6-10. F_{SW} = 400 kHz, 3.3 VOUT, Auto Mode

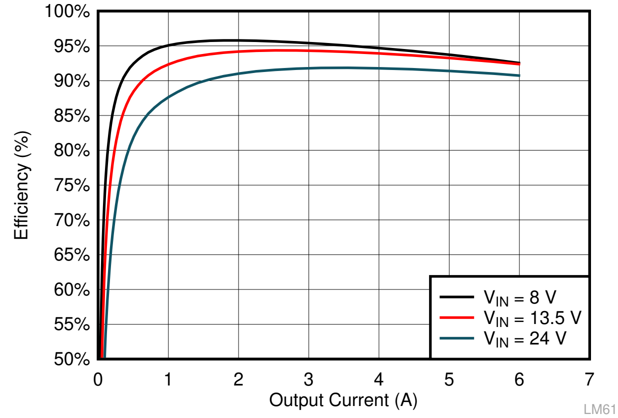

Figure 6-11. F_{SW} = 400 kHz, 3.3 VOUT, FPWM Mode

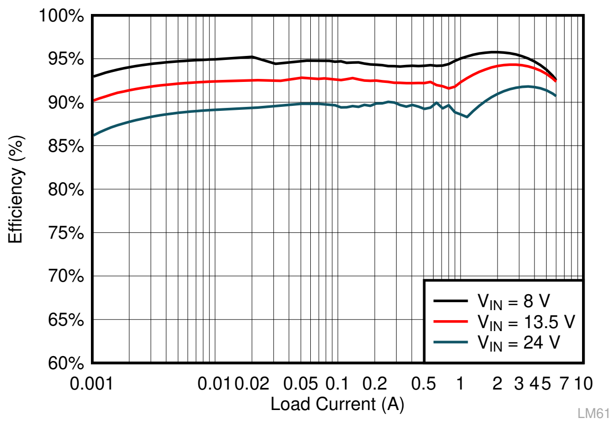

Figure 6-12. F_{SW} = 2.2 MHz, 5 VOUT, Auto Mode

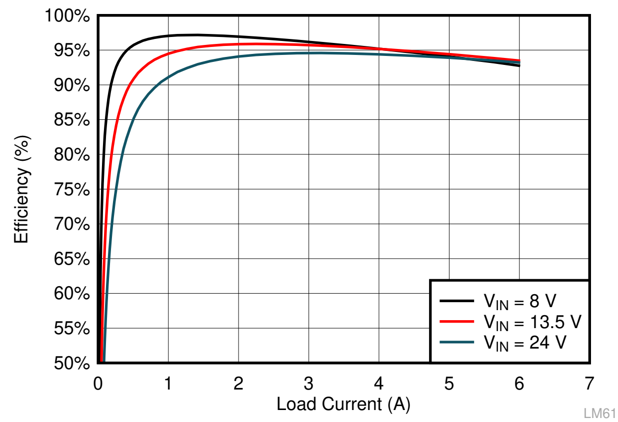

Figure 6-13. F_{SW} = 2.2 MHz, 5 VOUT, FPWM Mode

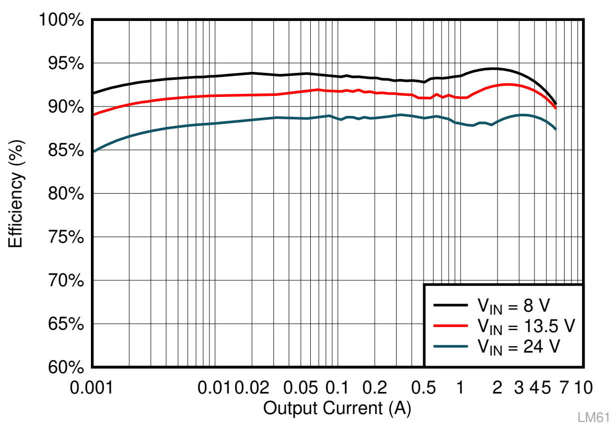

Figure 6-14. F_{SW} = 2.2 MHz, 3.3 VOUT, Auto Mode

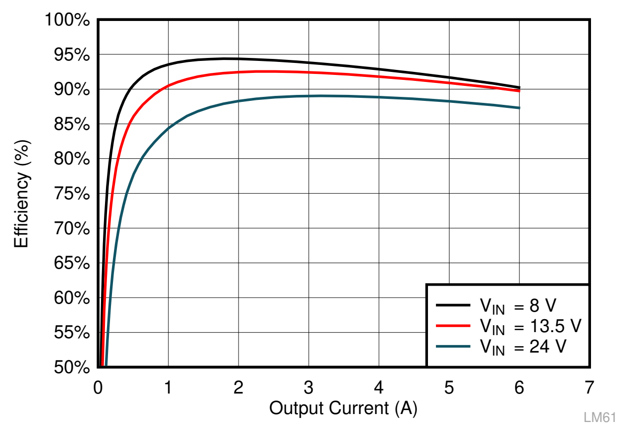

Figure 6-15. F_{SW} = 2.2 MHz, 3.3 VOUT, FPWM Mode

6.3 Load Regulation

This section provides efficiency plots for the board with LM61460AAS populated for Auto mode efficiency and LM61460AFS populated for FPWM mode efficiency. For 2-MHz data, the output stage has to be changed from the default BOM. The inductor (L1) selected was XEL5030-102MEB.

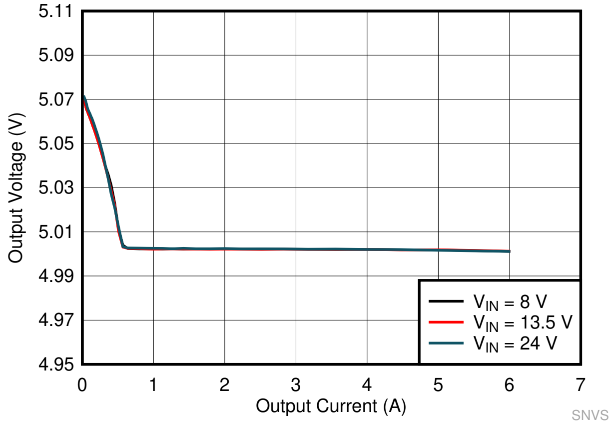

Figure 6-16. F_{SW} = 400 kHz, 5 VOUT, Auto Mode

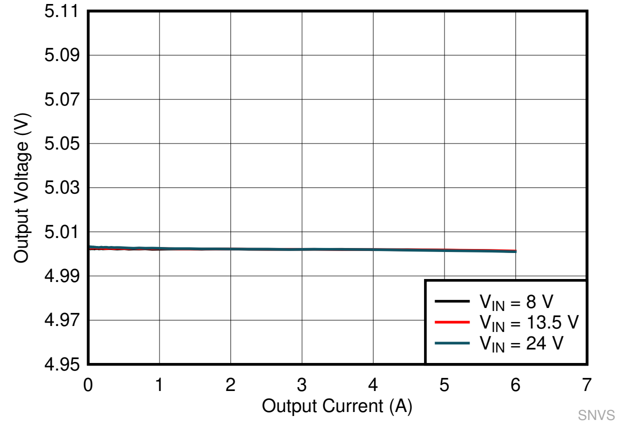

Figure 6-17. F_{SW} = 400 kHz, 5 VOUT, FPWM Mode

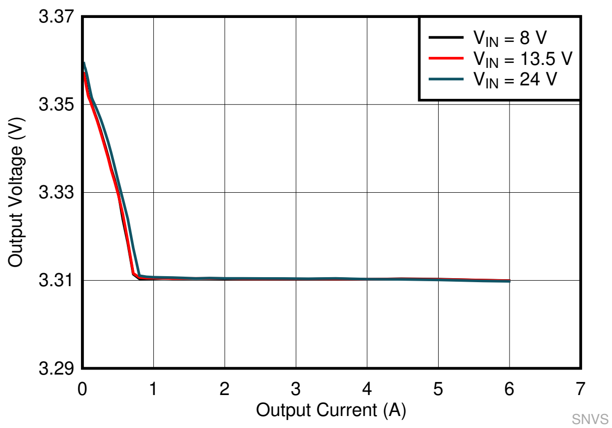

Figure 6-18. F_{SW} = 400 kHz, 3.3 VOUT, Auto Mode

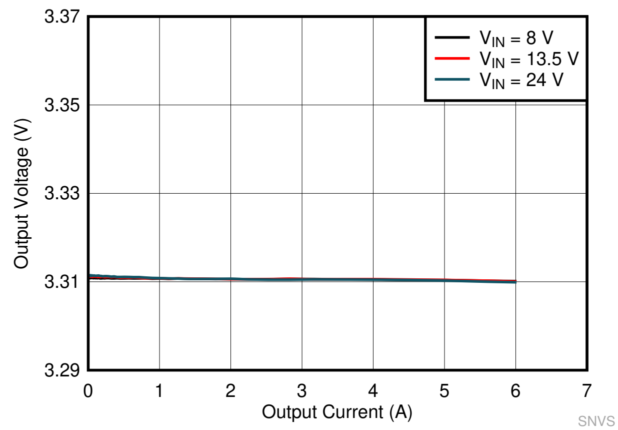

Figure 6-19. F_{SW} = 400 kHz, 3.3 VOUT, FPWM Mode

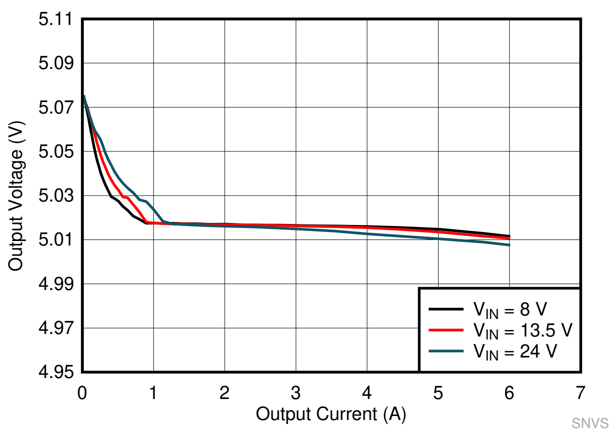

Figure 6-20. F_{SW} = 2.2 MHz, 5 VOUT, Auto Mode

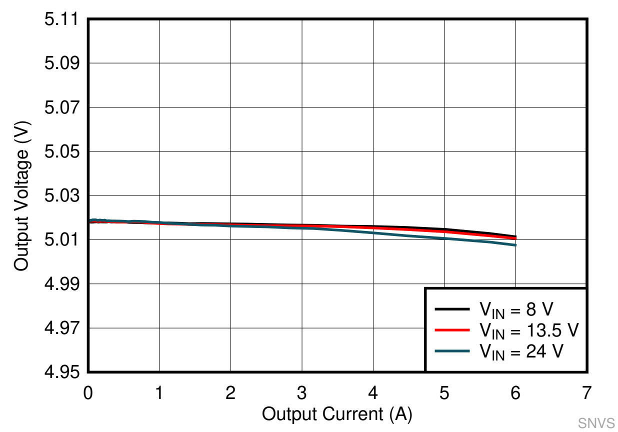

Figure 6-21. F_{SW} = 2.2 MHz, 5 VOUT, FPWM Mode

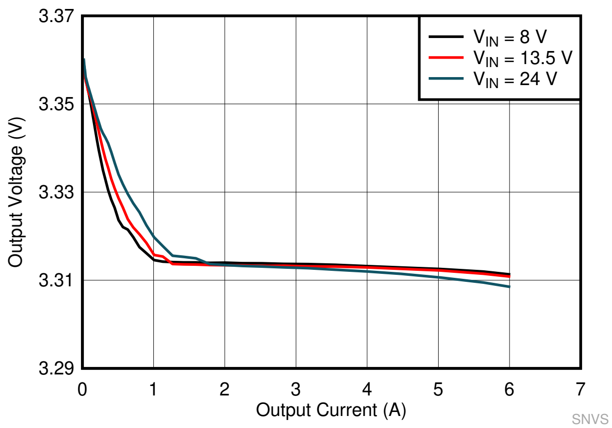

Figure 6-22. F_{SW} = 2.2 MHz, 3.3 VOUT, Auto Mode

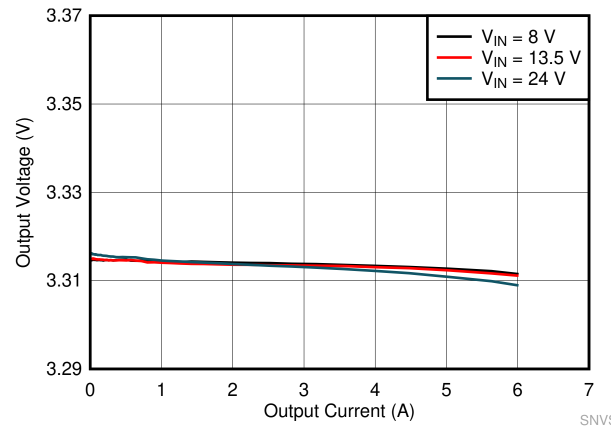

Figure 6-23. F_{SW} = 2.2 MHz, 3.3 VOUT, FPWM Mode

7 Bill of Materials

The bill of material is shown Table 7-1 for Rev A of the LM61460EVM-AS-400K and LM61460EVM-FS-400K. Note that the BOM difference between the two EVM variants is the selection of the IC populated (U1).

Table 7-1. LM61460EVM-xS-400K Rev A EVM Bill of Materials

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
C1, C4	2	4.7 µF	CAP, CERM, 4.7 µF, 50 V, ±20%, X7R, AEC-Q200 Grade 1, 1210	1210	UMK325B7475MMHT	Taiyo Yuden
C2, C3	2	0.022 µF	CAP, CERM, 0.022 µF, 50 V, ±10%, X7R, 0402	0402	GRM155R71H223KA12D	MuRata
C5	1	1 µF	CAP, CERM, 1 µF, 25 V, ±10%, X7R, 0805	0805	C0805C105K3RACTU	Kemet
C6, C7, C8, C9	4	22 µF	CAP, CERM, 22 µF, 16 V, ±20%, X7R, AEC-Q200 Grade 1, 1210	1210	CGA6P1X7R1C226M250AC	TDK
C12	1	1000 pF	CAP, CERM, 1000 pF, 50 V, ±0%, X7R, 0603	0603	C0603C102K5RACTU	Kemet
C13	1	0.1 µF	CAP, CERM, 0.1 µF, 10 V, ±10%, X7R, 0603	0603	C0603X104K8RACTU	Kemet
C15	1	1 µF	CAP, CERM, 1 µF, 16 V, ±10%, X7R, 0603	0603	885012206052	Wurth Elektronik
C16	1	22 pF	CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0603	0603	CGA3E2C0G1H220J080AA	TDK
C17, C18, C19, C20	4	2.2 µF	CAP, CERM, 2.2 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0805	0805	CGA4J3X7R1H225K125AB	TDK
C21, C22	2	0.47 µF	CAP, CERM, 0.47 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7R1H474K080AE	TDK
J1, J2, J3	3		Terminal Block, 5 mm, 2x1, Tin, TH	Terminal Block, 5 mm, 2x1, TH	691 101 710 002	Wurth Elektronik
J4	1		Header, 100 mil, 3x1, Gold, TH	Header, 100 mil, 3x1, TH	HTSW-103-07-G-S	Samtec
L1	1	4.7 µH	Inductor, Shielded, Hyperflux, 4.7 µH, 7.4 A, 0.0143 Ω, SMD	6.65x6.45 mm	74439346047	Wurth Elektronik
L2	1		1.2 µH Shielded Molded Inductor 7.5 A, 11.3 mΩ Max 2-SMD	SMD2	744316220	Wurth Electronics
LBL1	1			PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R1, R6	2	1.00 k	RES, 1.00 k, 1%, 0.25 W, 1206	1206	RC1206FR-071KL	Yageo America
R2	1	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL	Yageo
R3	1	33.2 k	RES, 33.2 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060333K2FKEA	Vishay-Dale
R4, R7	2	100 k	RES, 100 k, 1%, 0.1 W, 0603	0603	RC0603FR-07100KL	Yageo
R5	1	100	RES, 100, 1%, 0.1 W, 0603	0603	RC0603FR-07100RL	Yageo
R8	1	24.9 k	RES, 24.9 k, 1%, 0.1 W, 0603	0603	RC0603FR-0724K9L	Yageo
R9	1	1.00 k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1001V	Panasonic
R10	1	255 k	RES, 255 k, 1%, 0.1 W, 0603	0603	RC0603FR-07255KL	Yageo

Table 7-1. LM61460EVM-xS-400K Rev A EVM Bill of Materials (continued)

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER
SH-J1	1		Shunt, 100 mil, Gold plated, Black	Shunt 2 pos. 100 mil	881545-2	TE Connectivity
TP1, TP9	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP2, TP3, TP5, TP6	4		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
TP4, TP7	2		Test Point, Multipurpose, Orange, TH	Orange Multipurpose Testpoint	5013	Keystone
TP8, TP10	2		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone
U1 (**changes based on EVM variant**)	1		Automotive 6-A Low Noise Synchronous Buck Regulators, RJR0014A (VQFN-HR-14)	RJR0014A	LM61460AASQRJRRQ1 (LM61460EVM-AS-400K) or LM61460AFSQRJRRQ1 (LM61460EVM-FS-400K	Texas Instruments
C10, C11	0	22 µF	CAP, CERM, 22 µF, 16 V, ±20%, X7R, AEC-Q200 Grade 1, 1210	1210	CGA6P1X7R1C226M250AC	TDK
C14	0	1 µF	CAP, CERM, 1 µF, 10 V, ±10%, X7R, 0603	0603	GRM188R71A105KA61D	MuRata
C23, C24	0	1 µF	CAP, CERM, 1 µF, 50 V, ±10%, X7R, 0603	0603	UMK107AB7105KA-T	Taiyo Yuden
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R11, R12	0	0.51	RES, 0.51, 1%, 0.25 W, 0805	0805	CRM0805-FX-R510ELF	Bourns
R13	0	100 k	RES, 100 k, 1%, 0.1 W, 0603	0603	RC0603FR-07100KL	Yageo

8 Revision History

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

Changes from Revision C (December 2019) to Revision D (July 2021)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document.	6
• Added R11 to Section 7	18

Changes from Revision B (November 2019) to Revision C (December 2019)	Page
• Added plots to *Section 6.1*	13
• Added *Section 6.2*	14
• Added *Section 6.3*	16

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。

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

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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 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.

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