User's Guide

TPS56C230 Buck Converter Evaluation Module User's Guide

ABSTRACT

This user's guide contains information for the TPS56C230EVM evaluation module as well as for the TPS56C230 dc/dc converter. Also included are the performance specifications, schematic, layout and the list of materials for the TPS56C230EVM.

Table of Contents

Trademarks

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1 Introduction

The TPS56C230 is a synchronous buck converter designed to provide up to a 12-A output. The input voltage is rated for 4.5 V to 18 V. The TPS56C230 uses a proprietary D-CAP3™ control mode. It provides a fast transient response with no external compensation, and supports low ESR output capacitors. A MODE pin is used to set Forced Continuous Conduction Mode (FCCM) or Advanced Eco-mode operation. Rated input voltage and output current range for the evaluation module are given in Table 1-1. The high-side and low-side switching MOSFETs are integrated inside the TPS56C230 package along with the gate-driver circuitry. The low drain-to-source on resistance of the MOSFET allows the TPS56C230 to achieve high efficiencies and helps keep the junction temperature low at high output currents. An external divider allows for an adjustable output voltage. Additionally, the TPS56C230 provides adjustable soft start and undervoltage lockout inputs and an open drain power good output.

The TPS56C230EVM evaluation module (EVM) is a single, synchronous buck converter providing 1.2 V at 12 A from 4.5 V to 18 V input. This user's guide describes the TPS56C230EVM performance.

Table 1-1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE (V_{IN}) Range	OUTPUT CURRENT (I_{OUT}) Range
TPS56C230EVM	4.5 V to 18 V	0 A to 12 A

2 Performance Specification Summary

A summary of the TPS56C230EVM performance specifications is provided in Table 2-1. Specifications are given for an input voltage of 12 V and an output voltage of 1.2 V, unless otherwise specified. The ambient temperature is 25°C for all measurement, unless otherwise noted.

Table 2-1. TPS56C230EVM Performance Specifications Summary

SPECIFICATIONS	TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IN} Input voltage			4.5	12	18	V
V_{IN} start voltage				Internal UVLO		V
V_{IN} stop voltage				Internal UVLO		V
Output voltage setpoint				1.2		V
Output current range	V_{IN} = 4.5 V to 18 V		0		12	A
Line regulation	I_{OUT} = 6 A, V_{IN}= 4.5 V to 17 V			± 0.05%		
Load regulation	V_{IN} = 12 V, I_{OUT} = 0 to 12 A			-0.02%, +0.25%		
Load transient response	I_{OUT} = 1.2 A to 10.8 A	Voltage change		-38		mV
		Recovery time		75		µs
	I_{OUT} = 10.8 A to 1.2 A	Voltage change		48		mV
		Recovery time		50		µs
Loop bandwidth	V_{IN} = 12 V, I_{OUT} = 6 A			126.5		kHz
Phase margin	V_{IN} = 12 V, I_{OUT} = 6 A			72.5		degree
Input ripple voltage	V_{IN} = 12 V, I_{OUT} = 12 A			290		mVPP
Output ripple voltage	V_{IN} = 12 V, I_{OUT} = 12 A			16		mVPP
Output rise time	Soft start pin floating			1.5		ms
Maximum efficiency	TPS56C230EVM, V_{IN} = 12 V, I_{OUT} = 4 A			89.75%		

3 Modifications

The evaluation module is designed to provide access to the features of the TPS56C230. Some modifications can be made to this module.

3.1 Output Voltage Setpoint

The output voltage is set by the resistor divider network of R4 (R_{TOP}) and R6 (R_{BOT}). R6 is fixed at 10.0 kΩ. To change the output voltage of the EVM, it is necessary to change the value of resistor R4. Changing the value of R4 can change the output voltage above the 0.6 V reference voltage V_{REF}. The value of R4 for a specific output voltage can be calculated using Equation 1.

$$R_{(TOP)} = \frac{R_{(BOT)} \cdot (V_{OUT} - V_{REF})}{V_{REF}} \quad (1)$$

3.2 Mode Selection

TPS56C230 has a MODE pin to select the operation mode. The device reads the voltage on MODE pin during start-up and latches onto one of the MODE options listed below in Table 3-1.

Table 3-1. Mode Pin Resistor Settings

VOLTAGE ON MODE	R9/10/11/12 (kΩ)	R13/14/15/16 (kΩ)	OPERATION	FREQUENCY (kHz)
(0~10%)*VCC	330	15	Eco-mode	500
(10~20%)*VCC	180	33	FCCM	500

Change the position of the jumper on J4 to modify the MODE configuration before start up.

4 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS56C230EVM evaluation module. The section also includes test results typical for the evaluation module and covers efficiency, output voltage regulation, line regulation, load transient response, output voltage ripple, input voltage ripple, start-up and power-off.

4.1 Input/Output Connections

The TPS56C230EVM is provided with input/output connectors and test points as shown in Table 4-1. A power supply capable of supplying greater than 5 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. The maximum load current capability is 12 A. Wire lengths must be minimized to reduce losses in the wires. Test point TP3 provides a place to monitor the V_{IN} input voltages with TP8 providing a convenient ground reference. TP5 is used to monitor the output voltage with TP11 as the ground reference.

Table 4-1. Connection and Test Points

REFERENCE DESIGNATOR	FUNCTION
J1	V_{IN} input connector. (see Table 1-1 for V_{IN} range)
J2	V_{OUT} output connector. 1.2 V at 12 A maximum.
J3	Soft start selection. Remove the shunt to set the soft start time as internal default value.
J4	MODE selection. Refer to Section 3.2.
J5	EN control. Shunt EN to GND to disable. Shunt EN to the other side to enable.
TP1	VCC
TP2	V_{IN} terminal
TP3	V_{IN} test point
TP4	V_{OUT} terminal
TP5	V_{OUT} test point
TP6	SW node test point
TP7	Test point between voltage divider network and output. Used for loop response measurements.
TP8~11	GND test point
TP12	PGOOD test point
TP13~15	GND test point
TP16	EN test point

4.2 Efficiency

Figure 4-1 shows the efficiency for the TPS56C230EVM in 500kHz/Eco mode. The ambient temperature is 25 °C.

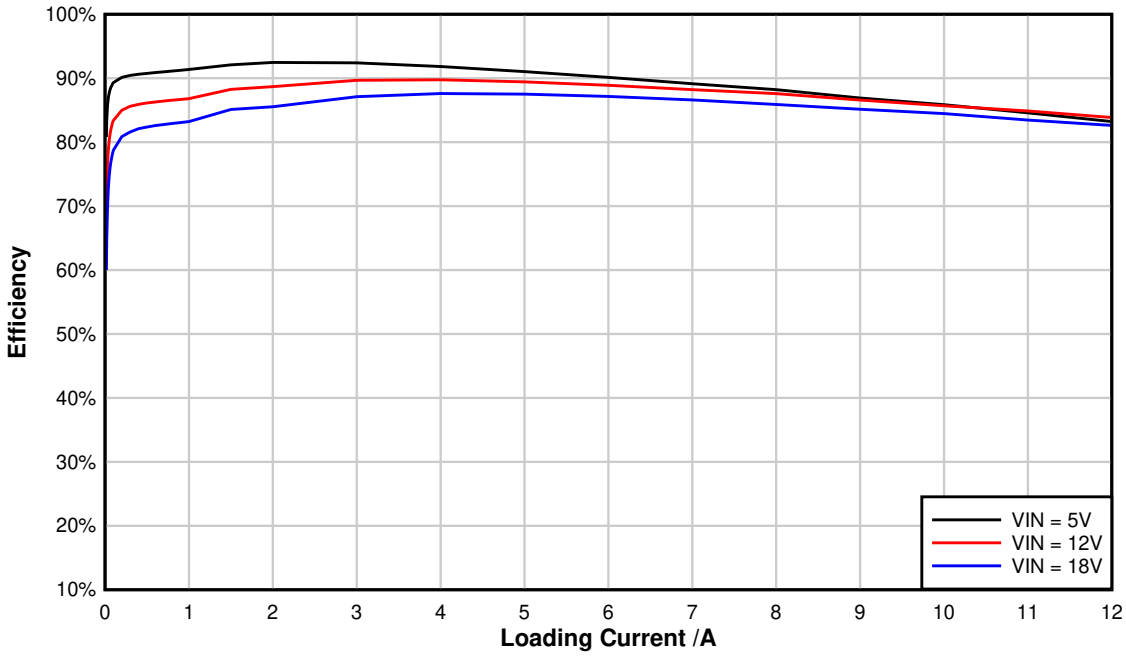

Figure 4-1. TPS56C230EVM Efficiency at 500-kHz/Eco mode

Figure 4-2 shows the efficiency at light loads for the TPS56C230EVM using a semi-log scale. The ambient temperature is 25 °C.

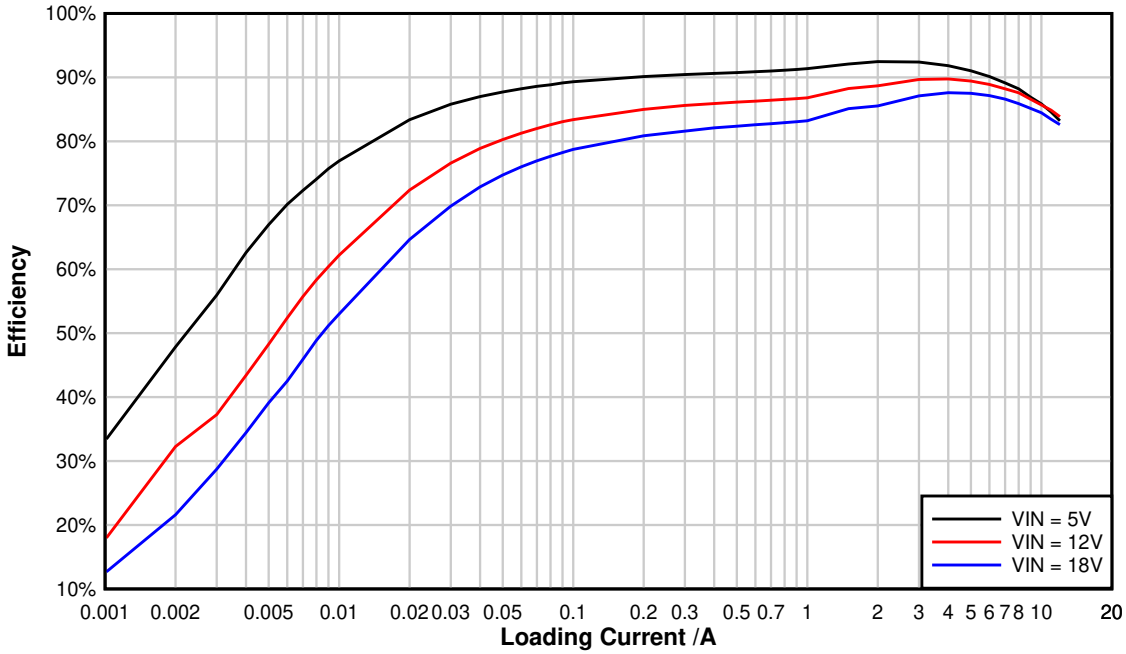

Figure 4-2. TPS56C230EVM Light Load Efficiency at 500-kHz/Eco Mode

The efficiency may be lower at higher ambient temperature, due to temperature variation in the drain-to-source resistance of the internal MOSFET.

4.3 Output Voltage Load Regulation

Figure 4-3 shows the load regulation for the TPS56C230EVM. Measurement is given for an ambient temperature of 25 °C.

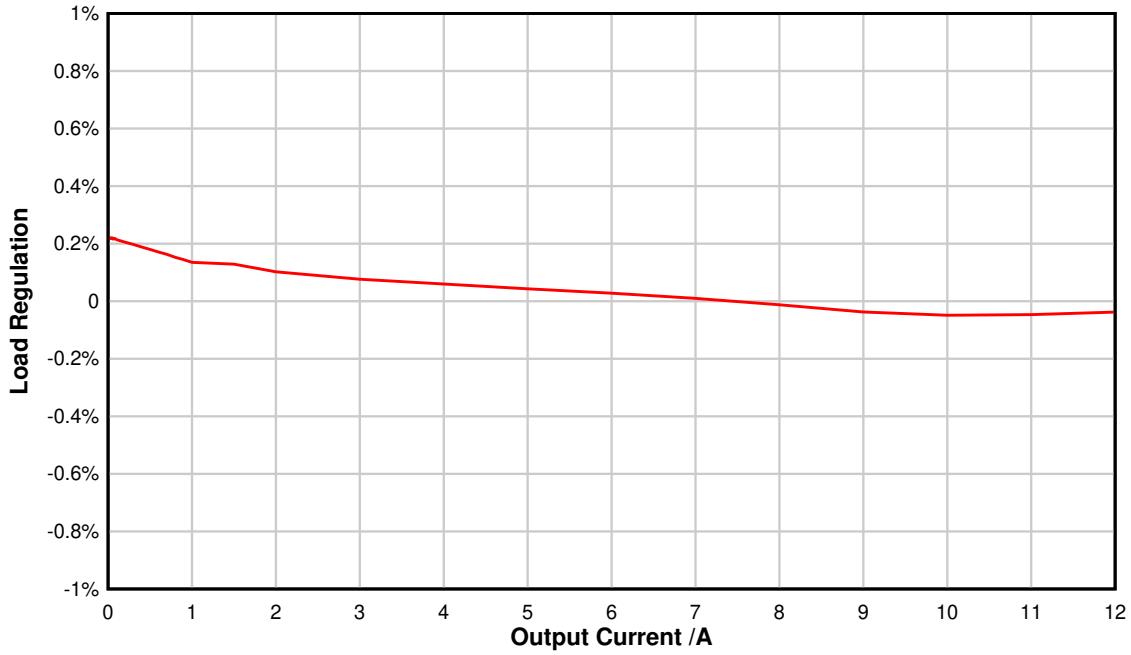

Figure 4-3. TPS56C230EVM Load Regulation, V_{IN} = 12 V

4.4 Output Voltage Line Regulation

Figure 4-4 shows the line regulation for the TPS56C230EVM. Measurement is given for an ambient temperature of 25 °C.

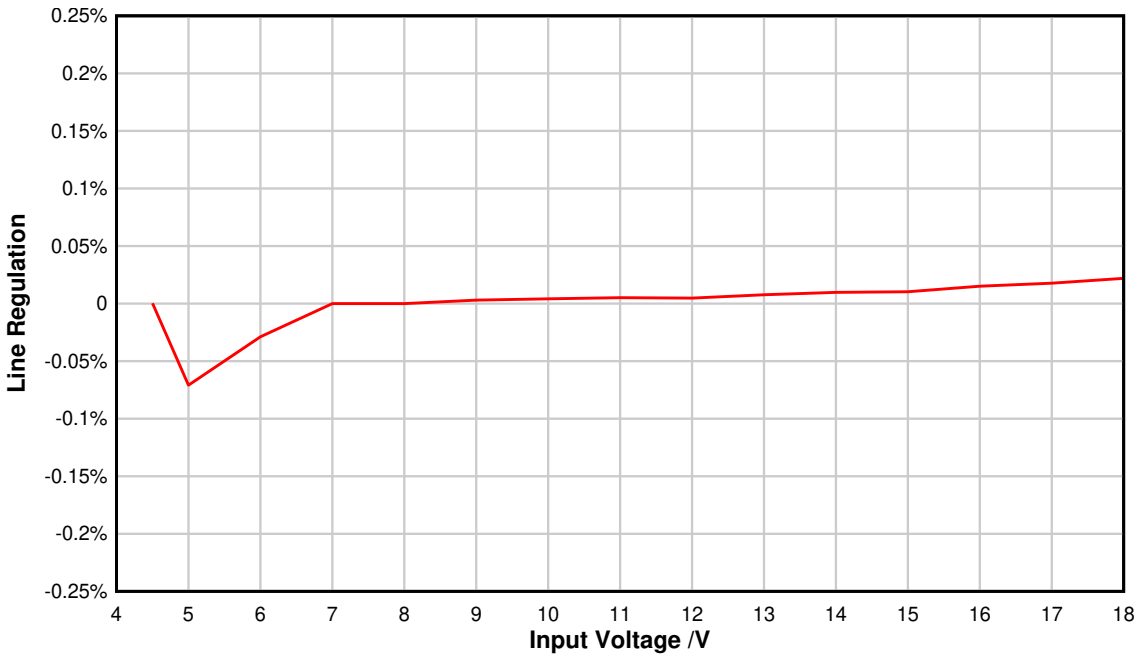

Figure 4-4. TPS56C230EVM Line Regulation

4.5 Load Transient Response

The TPS56C230EVM response to load transient is shown in Figure 4-5. The current steps and slew rates are indicated in the following figures . Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

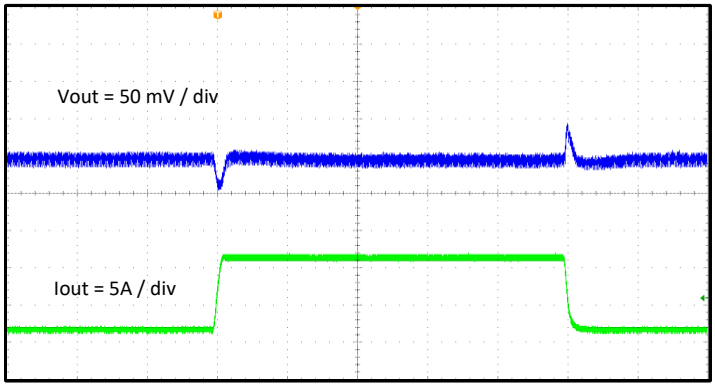

Figure 4-5. TPS56C230EVM Load Transient Response

4.6 Output Voltage Ripple

Figure 4-6, Figure 4-7, Figure 4-8 show the TPS56C230EVM output voltage ripple. The load currents are 10 mA, 800 mA, and 12 A. V_{IN} = 12 V. The ripple voltage is measured directly across TP5 and TP11.

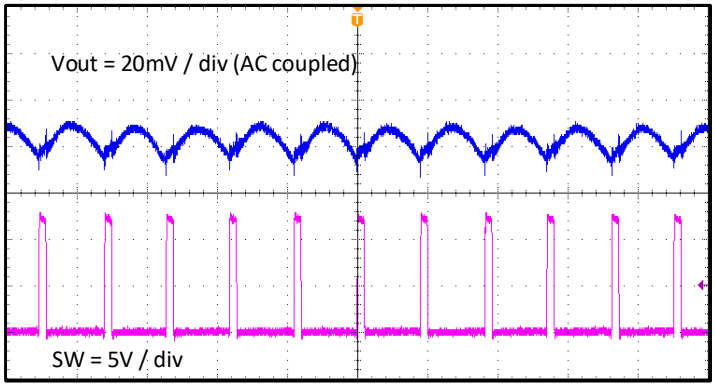

Figure 4-6. TPS56C230EVM Output Ripple, 10-mA Load

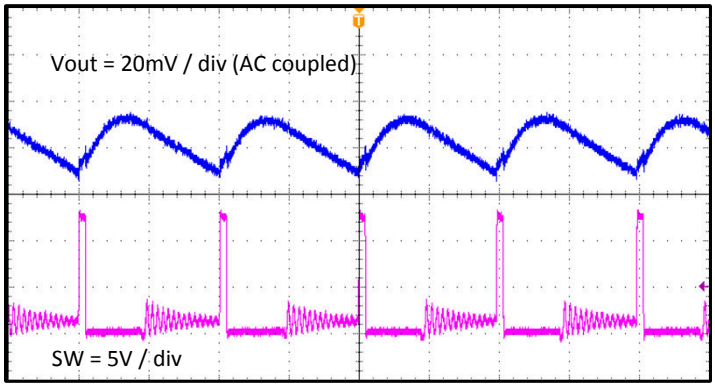

Figure 4-7. TPS56C230EVM Output Ripple, 800-mA Load

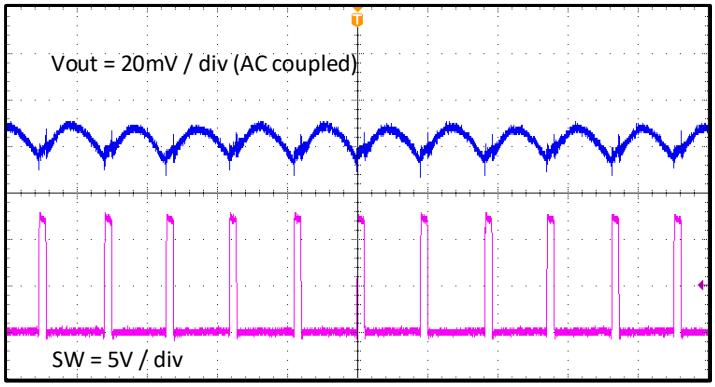

Figure 4-8. TPS56C230EVM Output Ripple, 12-A Load

4.7 Input Voltage Ripple

Figure 4-9, Figure 4-10 and Figure 4-11 show the TPS56C230EVM input voltage ripple at 500 kHz Eco-mode. The load currents are 10 mA, 800 mA and 12 A. The ripple voltage is measured directly across TP3 and TP8.

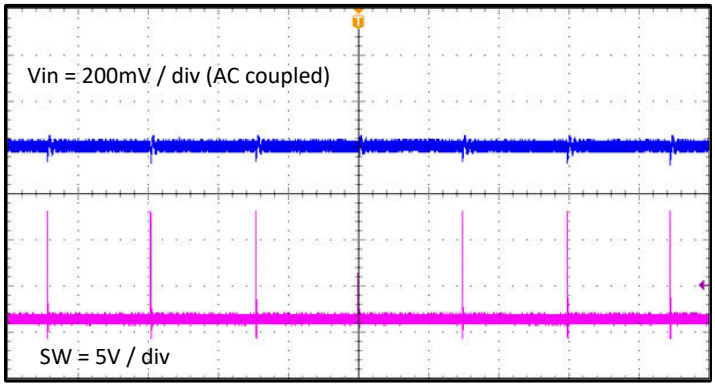

Figure 4-9. TPS56C230EVM Input Ripple, 10-mA Load

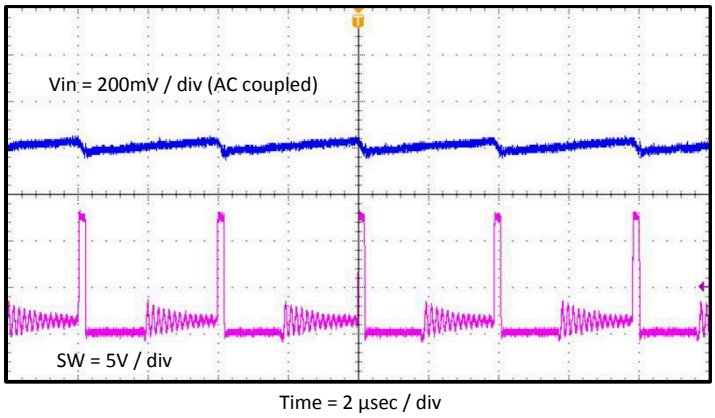

Figure 4-10. TPS56C230EVM Input Ripple, 800-mA Load

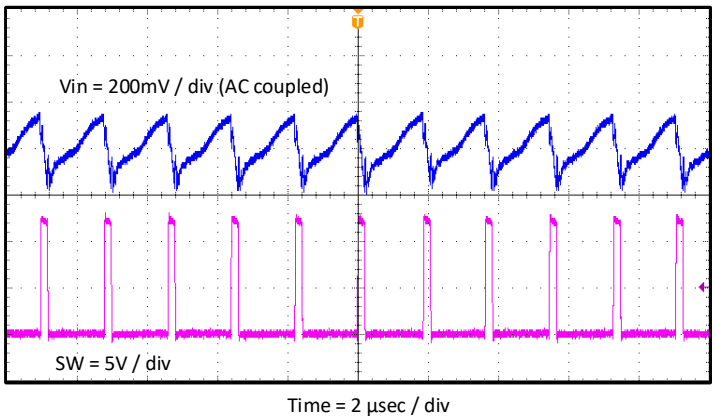

Figure 4-11. TPS56C230EVM Input Ripple, 12-A Load

4.8 Loop Characteristics

Figure 4-12 shows the TPS56C230EVM loop-response characteristics. Gain and phase plots are shown for V_{IN} voltage of 12 V. Load current for the measurement is 12 A.

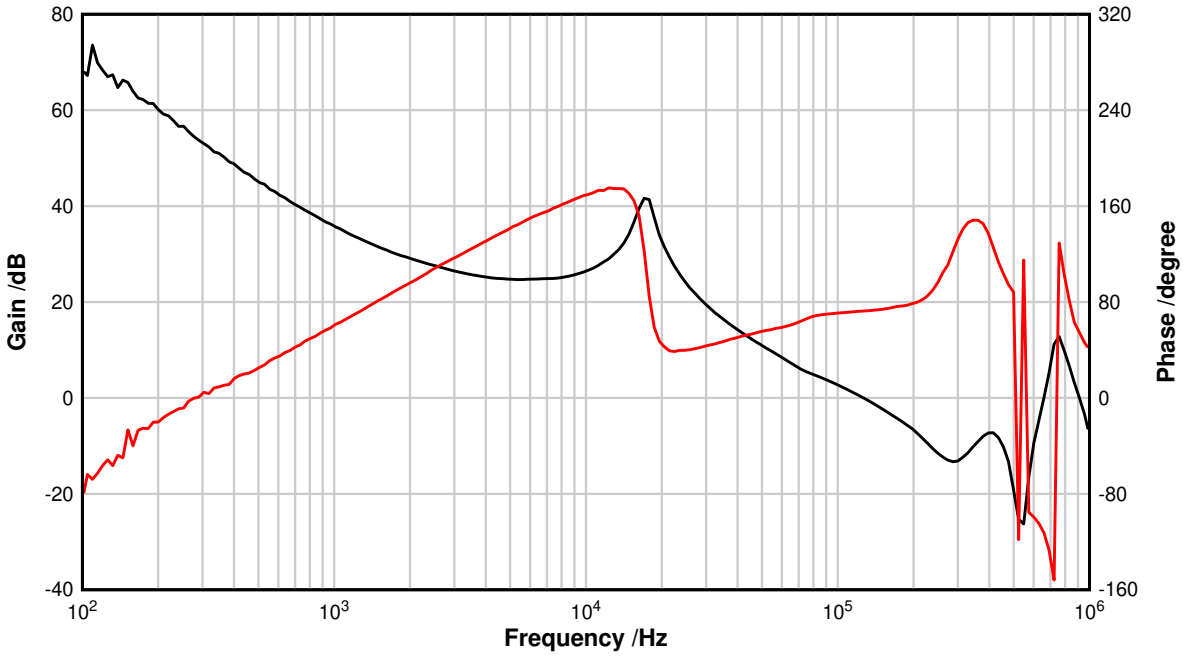

Figure 4-12. TPS56C230EVM Loop Response

4.9 Start-Up

Figure 4-13 and Figure 4-14 show the start-up waveforms for the TPS56C230EVM. In Figure 4-13, the output voltage ramps up as soon as the input voltage reaches the UVLO threshold. In Figure 4-14, the input voltage is initially applied and the output is inhibited by using a jumper at J5 to tie EN to GND. When the jumper is removed, EN is released. When the EN voltage reaches the enable-threshold voltage, the start-up sequence begins and the output voltage ramps up to the externally set value of 1.2 V. The input voltage for these plots is 12 V and the load is 1 Ω.

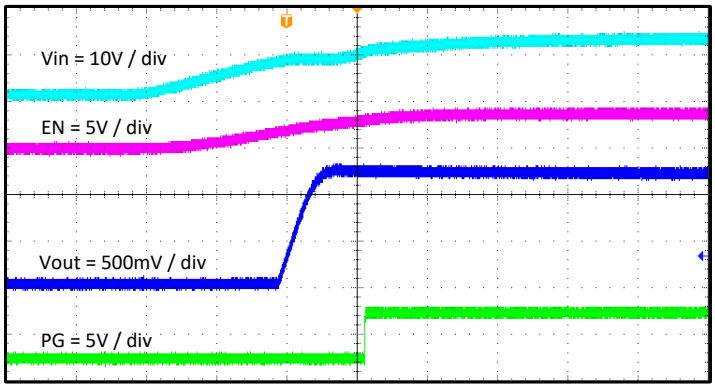

Figure 4-13. TPS56C230EVM Start-Up Relative to V_{IN}

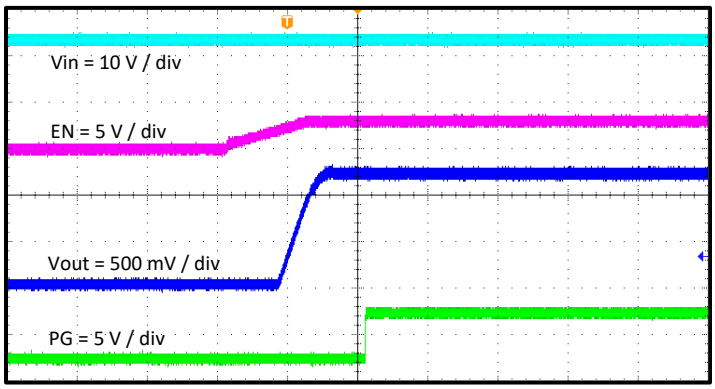

Figure 4-14. TPS56C230EVM Start-Up Relative to Enable

4.10 Shut-Down

Figure 4-15 and Figure 4-16 show the shutdown waveforms for the TPS56C230EVM. The input voltage for these plots is 12V and the load is 1Ω.

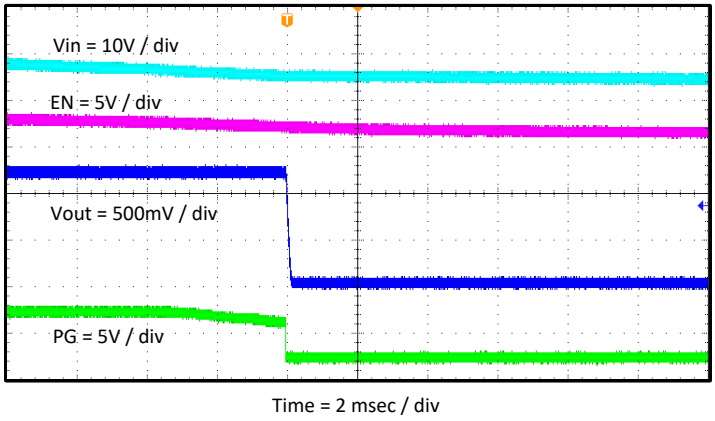

Figure 4-15. Shutdown Relative to V_{IN}

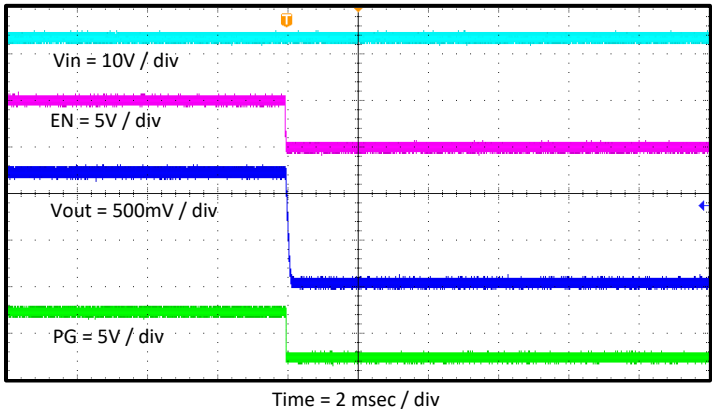

Figure 4-16. Shutdown Relative to Enable

5 Board Layout

This section provides a description of the TPS56C230EVM, board layout and layer illustrations.

5.1 Layout

The board layout for the TPS56C230EVM is shown in Figure 5-1 through Figure 5-5. The top and bottom layers are 2-oz copper thickness. Internal layers are 1-oz copper thickness.

The top layer contains the main power traces for VIN, VOUT and ground. Also on the top layer are connections for the pins of the TPS56C230 and a large area filled with ground. Most of the signal traces are located on the bottom left side, surrounding by a ground plane with an island for quiet analog ground that is connected to the main power ground at a single point. The internal layer-1 and internal layer-2 are dedicated ground planes. The bottom layer is another ground copper area with additional SW, VIN and VOUT copper fill. Ground traces on different layers are connected to each other with multiple vias placed on the board.

The input decoupling capacitors are located as close to the IC as possible. Critical analog circuits, such as the voltage set point divider, EN resister, SS capacitor, Mode resistor, VCC and AGND pin are terminated to quiet analog ground island on the top layer. The input and output connectors, test points and all of the components are located on the top side. The bottom layer is a ground plane along with the switching node copper fill, VIN and VOUT copper fill and the feedback trace from the point of regulation to the top of the resistor divider network.

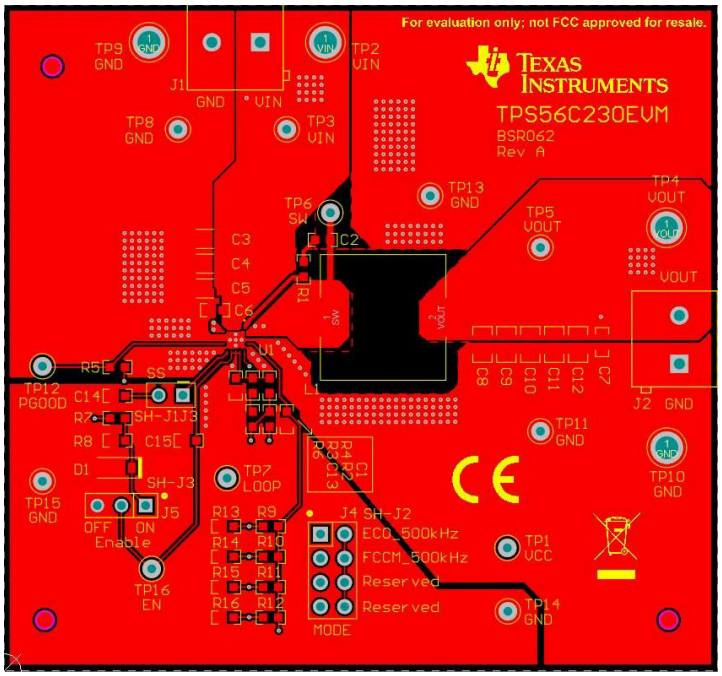

Figure 5-1. TPS56C230EVM Top-Side Assembly

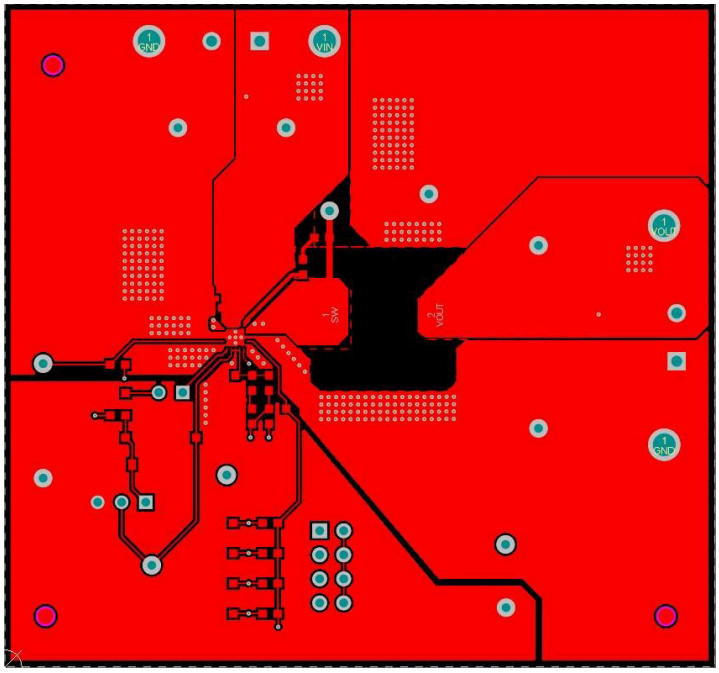

Figure 5-2. TPS56C230EVM Top-Side Layout

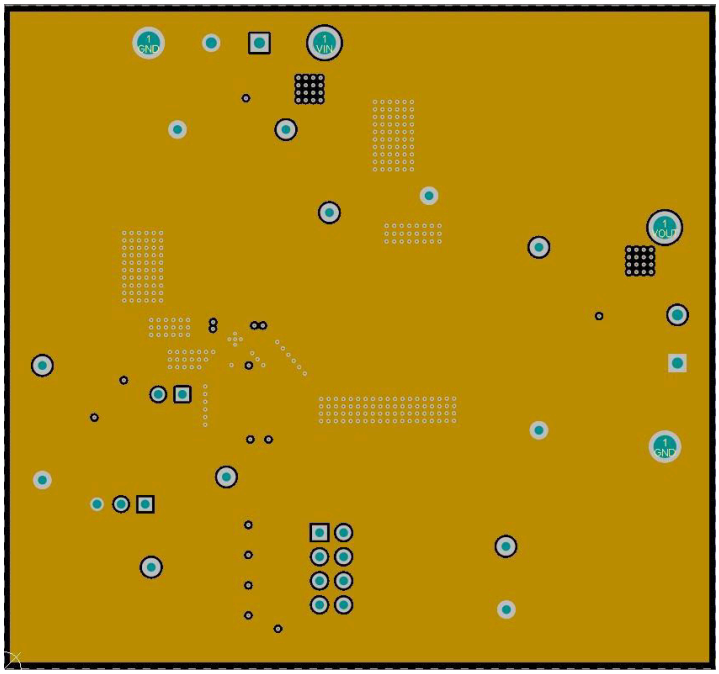

Figure 5-3. TPS56C230EVM Internal Layer-1 Layout

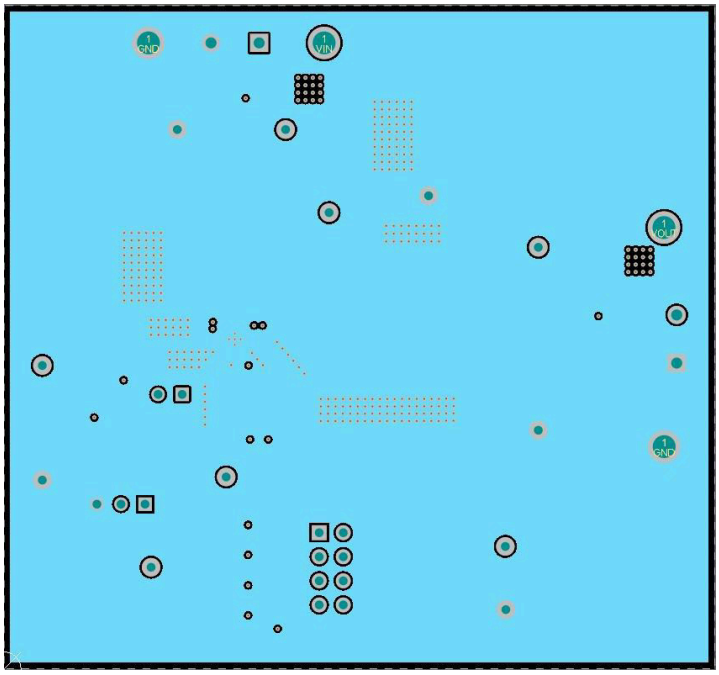

Figure 5-4. TPS56C230EVM Internal Layer-2 Layout

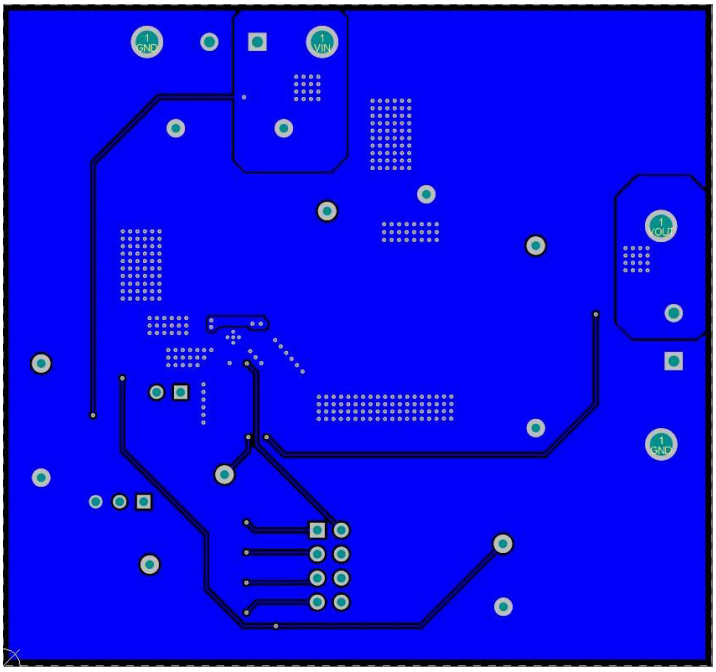

Figure 5-5. TPS56C230EVM Bottom Side Layout

6 Schematic, List of Materials, and Reference

6.1 Schematic

Figure 6-1 shows the schematic for TPS56C230EVM.

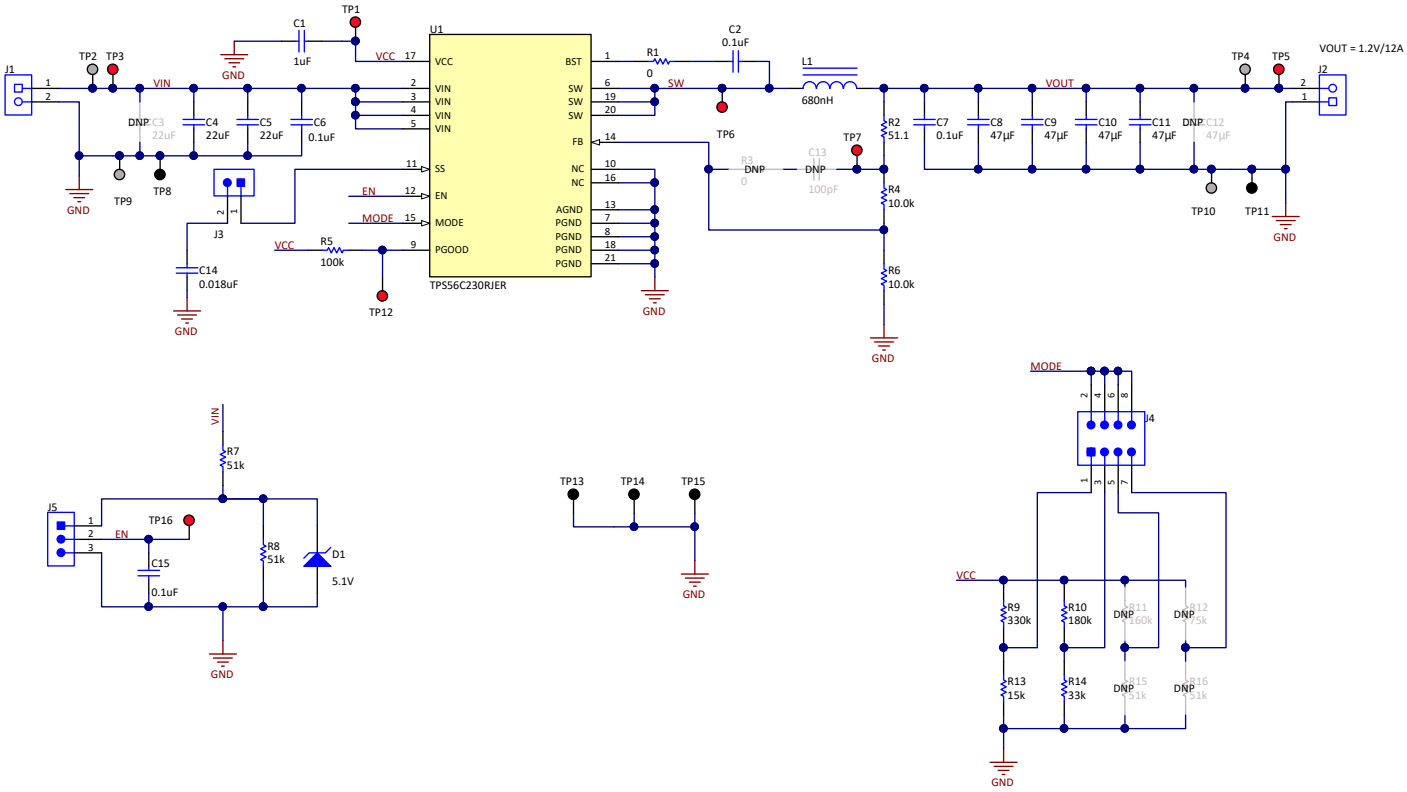

Figure 6-1. TPS56C230EVM Schematic

6.2 List of Materials

Table 6-1 presents the list of materials for the TPS56C230EVM.

Table 6-1. TPS56C230EVM List of Materials

DES	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
!PCB1	1	Printed circuit board	BSR062	Any
C1	1	Capacitor ceramic, 1 µF, 25 V, ±10%, X5R, 0603	C1608X5R1E105K080AC	TDK
C2, C6, C7, C15	4	Capacitor ceramic, 0.1 µF, 50 V, ±10%, X7R, 0603	C1608X7R1H104K080AA	TDK
C4, C5	2	Capacitor ceramic, 22 µF, 35 V, ±20%, X5R, 1206	C3216X5R1V226M160AC	TDK
C8, C9, C10, C11	4	Capacitor ceramic, 47 µF, 10 V, ±20%, X5R, 0805	GRM21BR61A476ME15L	MuRata
C14	1	Capacitor ceramic, 0.018 µF, 16 V, ±10%, X7R, 0603	GRM188R71C183KA01D	MuRata
D1	1	Diode, Zener, 5.1 V, 500 mW, SOD-123	MMSZ5231B-7-F	Diodes Inc.
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, 4x2, tin, TH	PEC04DAAN	Sullins Connector Solutions
J5	1	Header, 100 mil, 3x1, tin, TH	PEC03SAAN	Sullins Connector Solutions
L1	1	Inductor, shielded drum core, powdered iron, 680 nH, 17.5 A, 0.0018 ohm, SMD	744373770068	Wurth Elektronik
R1	1	Resistor, 0 Ω, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale
R2	1	Resistor, 51.1 Ω, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060351R1FKEA	Vishay-Dale
R4, R6	2	Resistor, 10.0 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060310K0FKEA	Vishay-Dale
R5	1	Resistor, 100 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603100KFKEA	Vishay-Dale
R7, R8	2	Resistor, 51 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060351K0JNEA	Vishay-Dale
R9	1	Resistor, 330 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603330KJNEA	Vishay-Dale
R10	1	Resistor, 180 kΩ, 1%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603180KJNEA	Vishay-Dale
R13	1	Resistor, 15 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060315K0JNEA	Vishay-Dale
R14	1	Resistor, 33 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060333K0JNEA	Vishay-Dale
SH-J1, SH-J2, SH-J3	3	Shunt, 100 mil, gold plated, black	SNT-100-BK-G	Samtec
TP1, TP3, TP5, TP6, TP7, TP12, TP16	7	Test point, miniature, red, TH	5000	Keystone
TP2, TP4, TP9, TP10	4	Terminal, turret, TH, triple	1598-2	Keystone
TP8, TP11, TP13, TP14, TP15	5	Test point, miniature, black, TH	5001	Keystone
U1	1	4.5-V to 18-V Input, 12-A Synchronous Step-Down Voltage Regulator, RJE0020B (VQFN-20)	TPS56C230RJER	Texas Instruments
C3	0	Capacitor ceramic, 22 µF, 35 V, ±20%, X5R, 1206	C3216X5R1V226M160AC	TDK
C12	0	Capacitor ceramic, 47 µF, 10 V, ±20%, X5R, 0805	GRM21BR61A476ME15L	MuRata
C13	0	Capacitor ceramic, 100 pF, 25 V, ±10%, X7R, 0603	06033C101KAT2A	AVX
FID1, FID2, FID3	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A
R3	0	Resistor, 0 Ω, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale
R11	0	Resistor, 160 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW0603160KJNEA	Vishay-Dale
R12	0	Resistor, 75 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060375K0JNEA	Vishay-Dale
R15, R16	0	Resistor, 51 kΩ, 5%, 0.1 W, AEC-Q200 grade 0, 0603	CRCW060351K0JNEA	Vishay-Dale

7 Revision History

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

Changes from Revision A (September 2019) to Revision B (June 2021)	Page
• Updated user's guide title	2
• Updated the numbering format for tables, figures, and cross-references throughout the document.	2

Changes from Revision * (January 2019 September 2019) to Revision A ()	Page
• Added updated List of Materials	18

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。

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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東京都新宿区西新宿 6 丁目 2 4 番 1 号
西新宿三井ビル

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

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

6. *Disclaimers:*

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

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

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

8. *Limitations on Damages and Liability:*

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

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

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

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

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

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