TEXAS INSTRUMENTS

TPS40009-Based, 5-A Converter in Less Than One Square Inch

User’s Guide

EVM IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation kit being sold by TI is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not considered by TI to be fit for commercial use. As such, the goods being provided may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety measures typically found in the end product incorporating the goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet the technical requirements of the directive.

Should this evaluation kit not meet the specifications indicated in the EVM User's Guide, the kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Please be aware that the products received may not be regulatory compliant or agency certified (FCC, UL, CE, etc.). Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive**.

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein**.

Please read the EVM User's Guide and, specifically, the EVM Warnings and Restrictions notice in the EVM User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact the TI application engineer.

Persons handling the product must have electronics training and observe good laboratory practice standards.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

DYNAMIC WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 0 V to 5.5 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 50°C. The EVM is designed to operate properly with certain components above 50°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

TPS40009-Based 5-A Converter in Less Than One Square Inch

Mark Dennis
Systems Power

Contents

1 Introduction

The TPS40009 is a voltage-mode, synchronous buck PWM controller that uses TI's proprietary Predictive Gate Drive™ technology to wring maximum efficiency from step-down converters. This controller provides a bootstrap charging circuit to allow the use of an N-channel MOSFET as the topside buck switch to reduce conduction losses and increase silicon device utilization. Predictive Gate Drive™ technology controls the delay from main switch turn-off to synchronous rectifier turn-on and also the delay from rectifier turn-off to main switch turn-on. This allows minimization of the losses in the MOSFET body diodes by reducing conduction and reverse recovery time. This user's guide provides details on a 5-A buck converter that converts 3.3 V down to a 1.2-V level using the TPS40009 controller, with less than one square inch board area.

A schematic for the board is shown in Figure 1. A list of material is provided in the final section.

2 Features

The specification for this board is as follows:

- V_{IN} = 3.0 V to 3.6 V
- V_{OUT} = 1.2 V ± 3%
- 0 A ≤ I_{OUT} ≤ 5 A
- Efficiency > 90% with a load of 2 A
- Output voltage ripple < 2% V_{OUT}
- Physical size < 1 square inch circuit area

3 Schematic

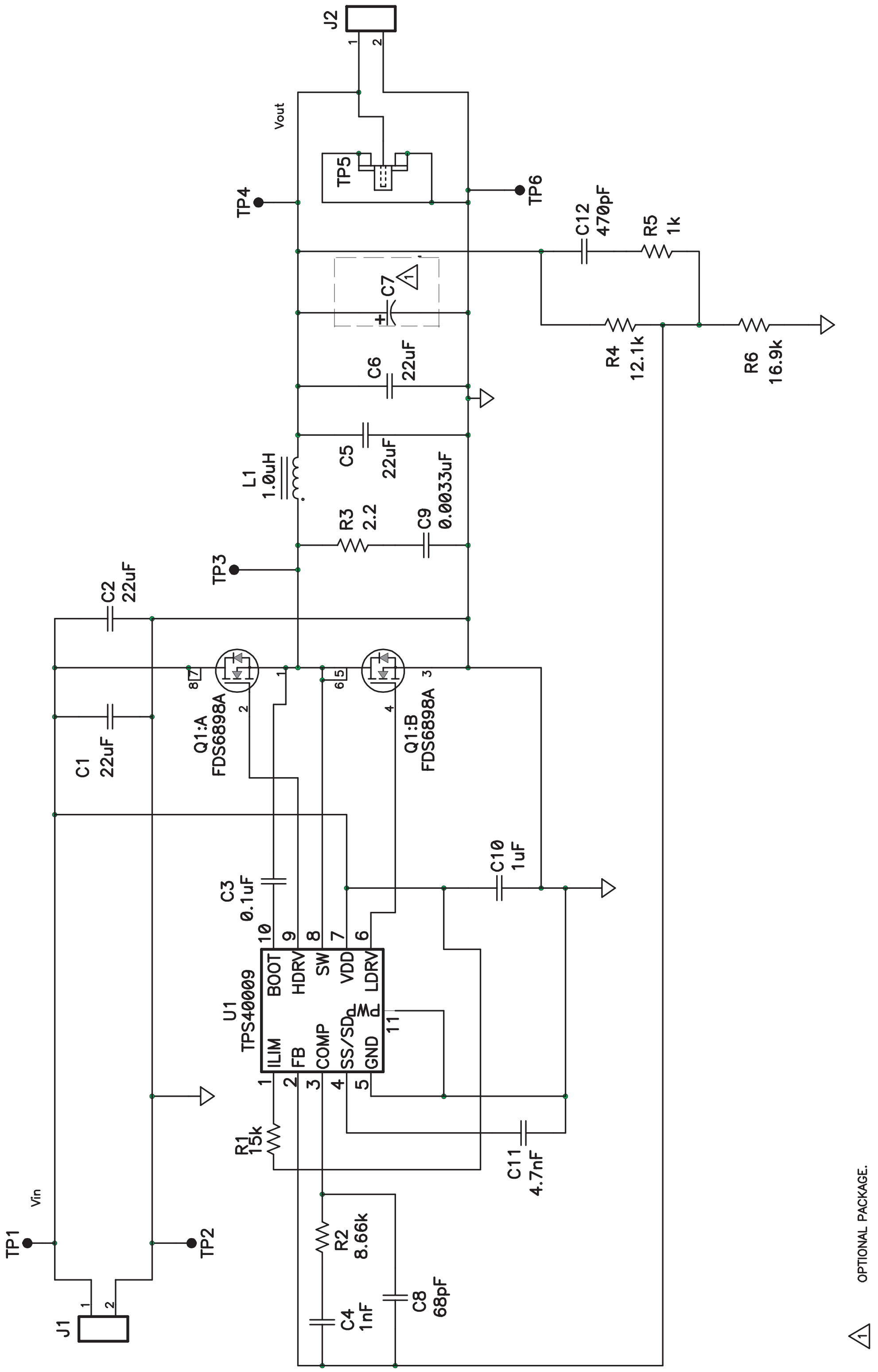


Figure 1. Application Diagram for the TPS40009

4 Design Procedure

4.1 Controller Selection

The TPS40009 synchronous buck controller is selected for this small size application because the 600-kHz switching frequency enables the selection of minimally sized filter components. The TPS40007 is available for applications needing 300-kHz operation for designs where efficiency is to be optimized.

4.2 Inductance Value

The output inductor value is selected to set the ripple current to a value most suited to overall circuit functionality. The inductor value is calculated in equation (1).

$$L = \frac{V_{OUT}}{f \times I_{RIPPLE}} \left(1 - \frac{V_{OUT}}{V_{IN(max)}} \right) = \frac{1.2\ V}{600\ kHz \times 1.25\ A} \times \left(1 - \frac{1.2\ V}{3.6\ V} \right) = 1.07\ \mu H \qquad (1)$$

where I_{RIPPLE} is chosen to be 25% of I_{OUT}, or 1.25 A. A common value of 1 µH is selected.

4.3 Input Capacitor Selection

Bulk input capacitor selection is based on allowable input voltage ripple and required RMS current carrying capability. In typical buck converter applications, the converter is fed from an upstream power converter with its own output capacitance. In this converter, onboard capacitance is provided to supply the current required during the top MOSFET on-time while keeping ripple within acceptable limits. For this power level, input voltage ripple of 150 mV is reasonable, and a conservative minimum value of capacitance is calculated in equation (2).

$$C = \frac{I \times \Delta t}{\Delta V} = \frac{5\ A \times 606\ ns}{0.15\ V} = 20\ \mu F \qquad (2)$$

To meet this requirement with the lowest size and cost, a single 22 µF, X5R ceramic capacitor might be considered. Although these capacitors have an extremely small resistance a typical datasheet indicates that the part undergoes a 30°C temperature rise with 2 A_{RMS} current at 500 kHz. With V_{IN} = 3.0 V our circuit requires nearly 2 A_{RMS} of current, so for a conservative design two capacitors are selected to allow for conservative current derating. These capacitors function as power bypass components and should be located near the MOSFET package, to keep the high frequency current flow in a tight loop. The low impedance characteristics of the dual ceramic capacitors help to reduce noise on the V_{DD} supply of the device. Specifically, the high side MOSFET current sense is referenced to this point, so noise at the device must be kept to a low level.

4.4 Output Capacitor Selection

Selection of the output capacitor is based on many application variables, including function, cost, size, and availability. The minimum allowable output capacitance is determined by the amount of inductor ripple current and the allowable output ripple in equation (3).

$$C_{OUT(min)} = \frac{I_{RIPPLE}}{8 \times f \times V_{RIPPLE}} = \frac{1.25\ A}{8 \times 600\ kHz \times 12\ mV} = 22\ \mu F \qquad (3)$$

In this design, $C_{OUT(min)}$ is 22 µF with V_{RIPPLE} = 12 mV to allow for some margin. However, this only affects the capacitive component of the ripple voltage. In addition, the voltage component due to the capacitor ESR must be considered in equation (4).

$$ESR_{Cout} \leq \frac{V_{RIPPLE}}{I_{RIPPLE}} = \frac{0.012\ V}{1.25\ A} = 9.6\ m\Omega \qquad (4)$$

For compactness while maintaining transient response capability, two 22-µF ceramic capacitors are fitted in parallel. The total ESR of these capacitors is below 3 mΩ, and contributes only a few mV to the output voltage ripple.

4.5 MOSFET Selection

The small physical size of this design requires the use of a single SO-8 package which contains dual N-channel MOSFETs. MOSFETs with an $R_{DS(on)}$ of 18 mΩ are selected to keep the conduction losses to a manageable amount at full load.

4.6 Short Circuit Protection

The TPS40009 implements short circuit protection by comparing the voltage across the topside MOSFET while it is on to a voltage dropped from VDD by R_{LIM} due to an internal current source of 15 µA inside pin 1. Due to tolerances in the current source and variations in the power MOSFET on-voltage versus temperature, the short circuit level can protect against gross overcurrent conditions only, and should be set higher than rated load. In this particular case, R_{LIM} is selected as:

$$R_{LIM} = R1 = \frac{2.5 \times I_{OUT} \times 0.018\ \Omega}{15\ \mu A} = 15\ k\Omega \qquad (5)$$

For this design, R_{LIM} = 15 kΩ, and the factor of 2.5 in the equation accounts for the variations in component tolerances over temperature and output current ripple.

4.7 Compensation Design

The TPS40009 uses voltage mode control in conjunction with a high frequency error amplifier. For the fastest transient response, the loop crossover frequency is set at 1/10 f_S, or 60 kHz. The power circuit L-C double pole corner frequency f_C is situated at 24 kHz, and the output capacitor ESR zero is far higher at approximately 1MHz. The feedback compensation network is implemented to provide two zeroes and three poles. The first pole is placed at the origin to improve dc regulation.

The first zero is placed at approximately 2/3 f_C, 18 kHz,

$$f_{z1} = \frac{1}{2 \times \pi \times R_2 \times C_4} \quad (6)$$

The second zero is selected at f_C,

$$f_{z2} = \frac{1}{2 \times \pi \times \left(R_4 + R_5\right) \times C_{12}} \quad (7)$$

The two poles are placed at approximately 300 kHz, which is one-half the switching frequency,

$$f_{p1} = \frac{1}{2 \times \pi \times R_2 \times \left(\frac{C_4 \times C_8}{C_4 + C_8}\right)} \quad (8)$$

and

$$f_{p2} = \frac{1}{2 \times \pi \times R_5 \times C_{12}} \quad (9)$$

Figure 2 shows the plots for the closed loop gain and phase with V_{IN} = 3.3 V and I_{OUT} = 4.4 A. At the crossover frequency of 60 kHz the phase margin is approximately 51 degrees.

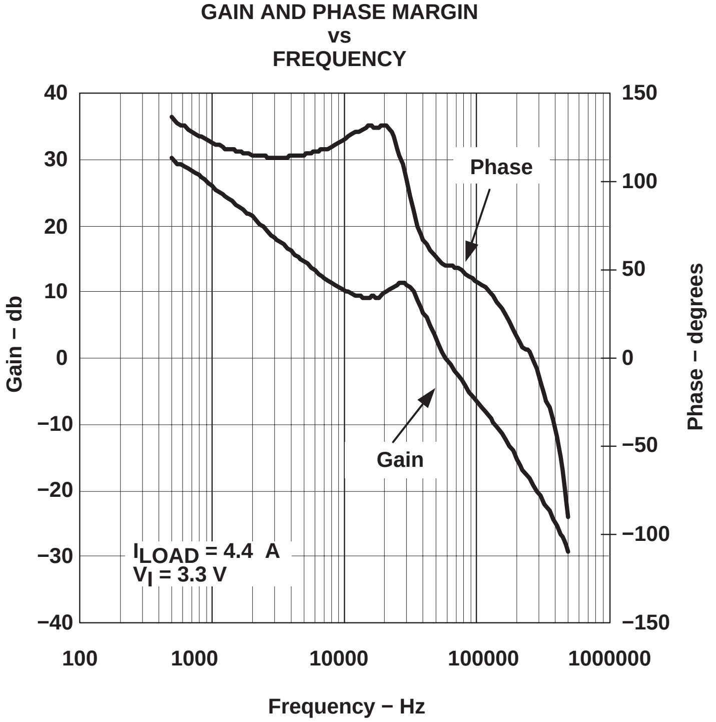


Figure 2.

4.8 Snubber Component Selection

The switch node where Q1 and L1 come together is very noisy. An R−C network fitted between this node and ground can help reduce ringing and voltage overshoot on Q1:B. This ringing noise should be minimized to prevent it from confusing the control circuitry which is monitoring this node for current limit and Predictive Gate Drive™.

As a starting point, the snubber capacitor, C9, is generally chosen to be 5 to 8 times larger than the parasitic capacitance at the node, which is primarily C_{OS} of Q1:B. Since C_{OS} is 440 pF for Q1:B, C9 is chosen to be 3.3 nF. R3 is empirically determined to be 2.2 Ω, which minimizes the ringing and overshoot at the switch node. With low input voltages the power loss, $1/2 \times C \times V^2 \times f$, is relatively small at 24 mW.

5 PowerPAD™ Packaging

The TPS4000X family is available in the DGQ version of TI's PowerPAD™ thermally enhanced package. In the PowerPAD™, a thermally conductive epoxy is used to attach the integrated circuit die to the leadframe die pad, which is exposed on the bottom of the completed package. The leadframe die pad can be soldered to the PCB using standard solder flow techniques when maximum heat dissipation is required. However, depending on power dissipation requirements, the PowerPAD™ may not need to soldered to the PCB.

The PowerPAD™ package helps to keep the junction temperature rise relatively low even with the power dissipation inherent in the onboard MOSFET drivers. This power loss is proportional to switching frequency, drive voltage, and the gate charge needed to enhance the N-channel MOSFETs. Effective heat removal allows the use of ultra small packaging while maintaining high component reliability.

To effectively remove heat from the PowerPAD™ package, a thermal land should be provided directly underneath the package whether the package needs to be soldered or not. This thermal land usually has vias that help to spread heat to internal copper layers and/or the opposite side of the PCB. The vias should not have thermal reliefs that are often used on ground planes, because this reduces the copper area which transfers heat. Additionally, the vias should be small enough so that the holes are effectively plugged when plated. This prevents the solder from wicking away from the connection between the PCB surface and the bottom of the part. A typical construction uses a few vias of 0.013" diameter plated with 1 ounce copper in the land under the TPS40009. A typical layout pattern is shown in Figure 2, but does not show the copper land which would encompass the vias above and below the device.

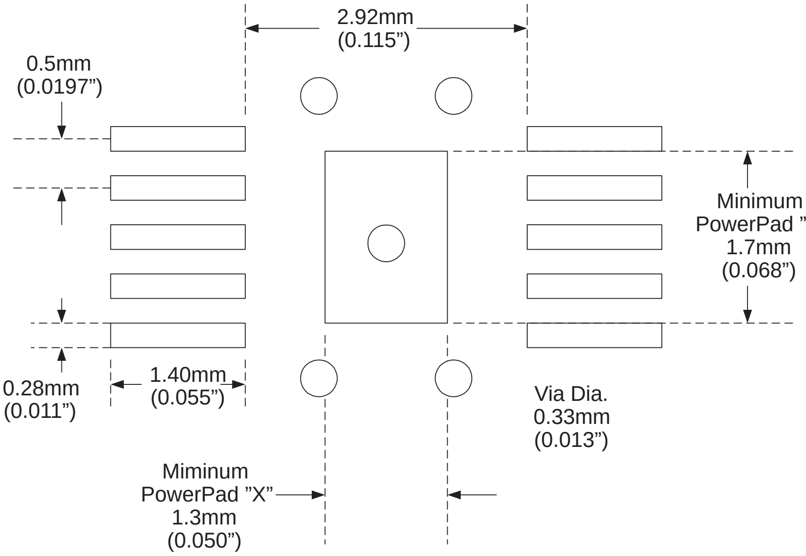


Figure 3. PowerPAD PCB Layout Guidelines

The Texas Instrument document, PowerPAD™ Thermally Enhanced Package Application Report (SLMA002) should be consulted for more information on the PowerPAD™ package. This report offers in-depth information on the package, assembly and rework techniques, and illustrative examples of the thermal performance of the PowerPAD™ package.

6 Test Results/Performance Data

The test setup is shown in figure 4

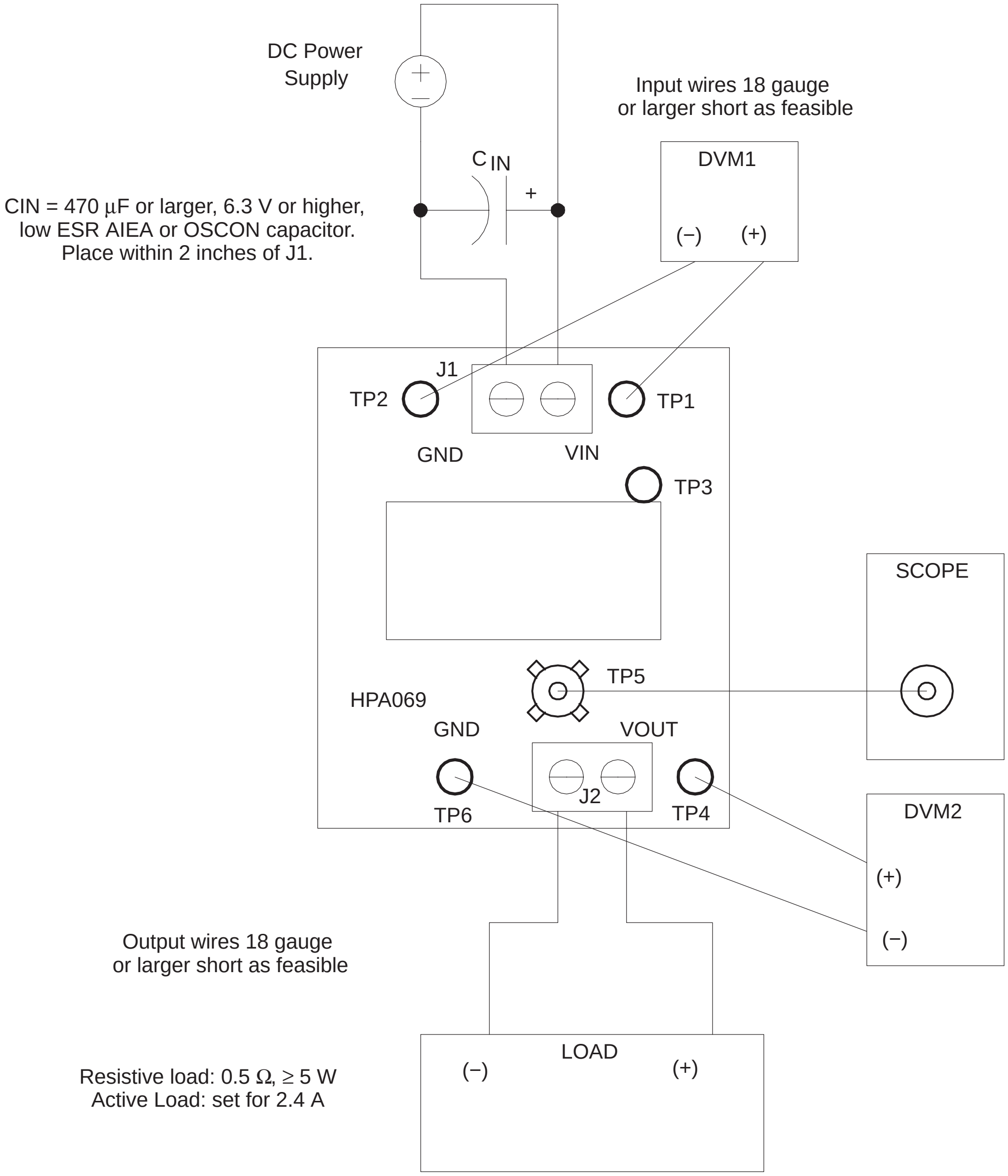


Figure 4.

Typical efficiency curves are shown in Figure 5 for an input of 3.3 V.

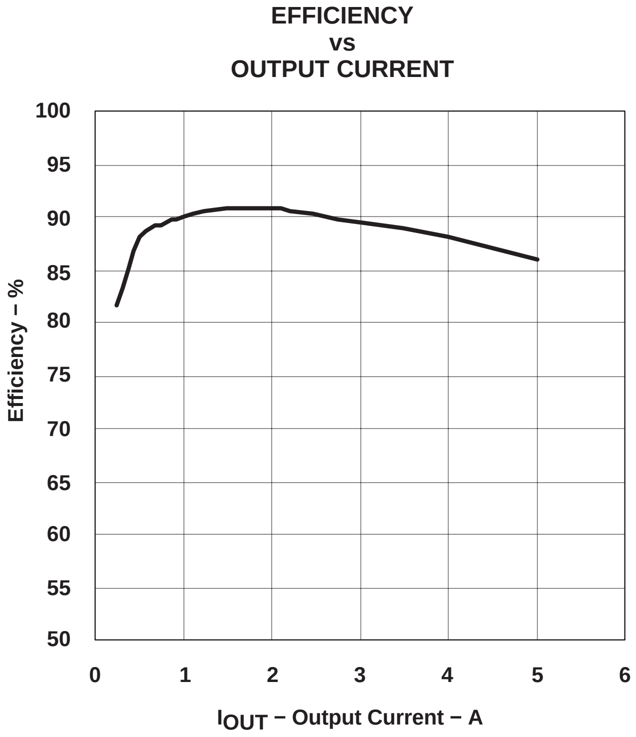


Figure 5.

Figure 6 shows the switch node during typical operation at full load. Note that there is very minimal body diode conduction in the bottom MOSFET. This is a result of using the predictive delay control implementation. This technique is able to dynamically change the delays in the MOSFET drive circuit to account for variations in line, load, and between devices.

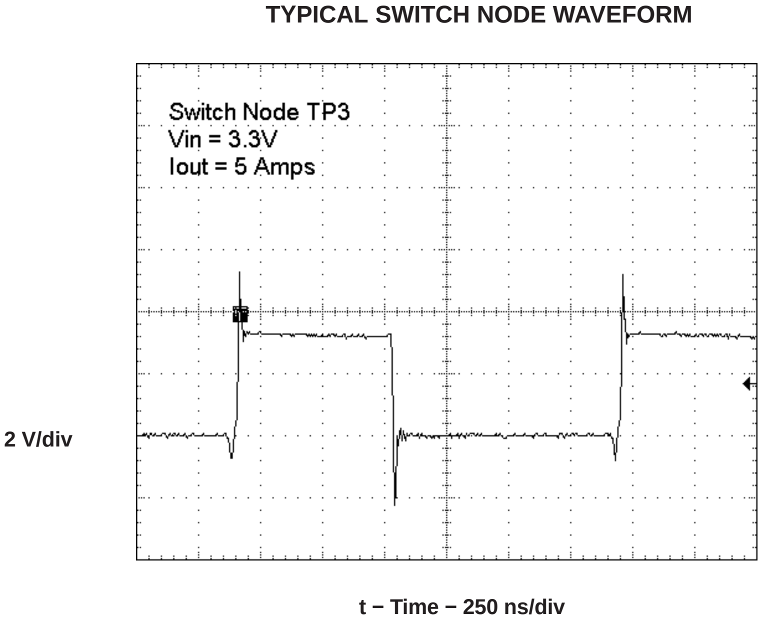


Figure 6.

Circuit operation with an output short circuit is shown in Figure 7. After each restart into a short circuit the pulses terminate for a period of approximately 6 ms. This causes the input power to collapse to minuscule levels, and the circuit is protected.

SHORT CIRCUIT OPERATION

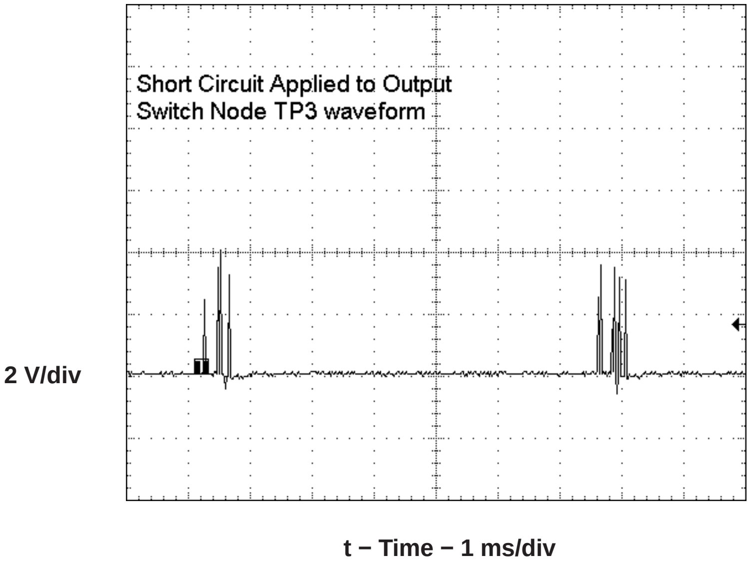


Figure 7.

Figure 8 shows the output voltage ripple which is approximately half the 24-mV limit.

OUTPUT VOLTAGE RIPPLE

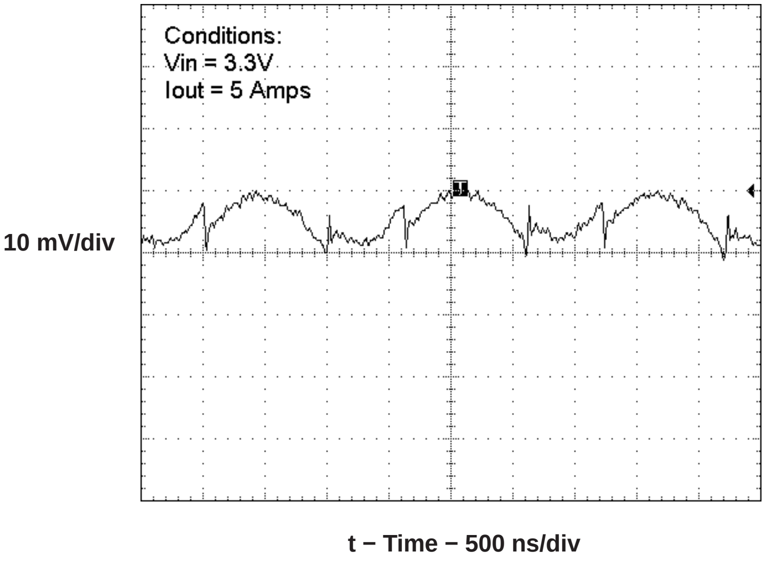


Figure 8.

Figure 9 shows the startup waveforms with an input voltage of 3.3 V and a load of 0.3 Ω. Note that the output is held low until V_{SS} (pin 4) goes above 0.12 V, and then the output comes up smoothly under closed loop softstart control.

STARTUP WAVEFORM

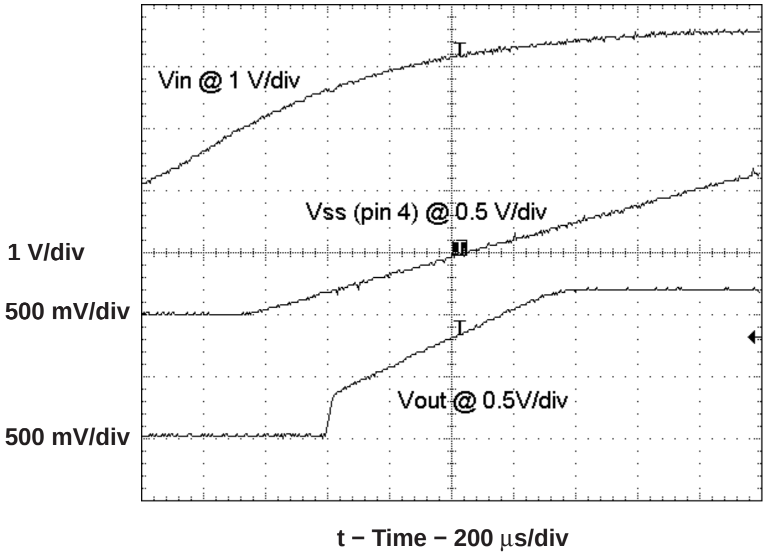


Figure 9.

Figure 10 shows the transient response for a fast load step from 1 A to 2 A.

TRANSIENT RESPONSE

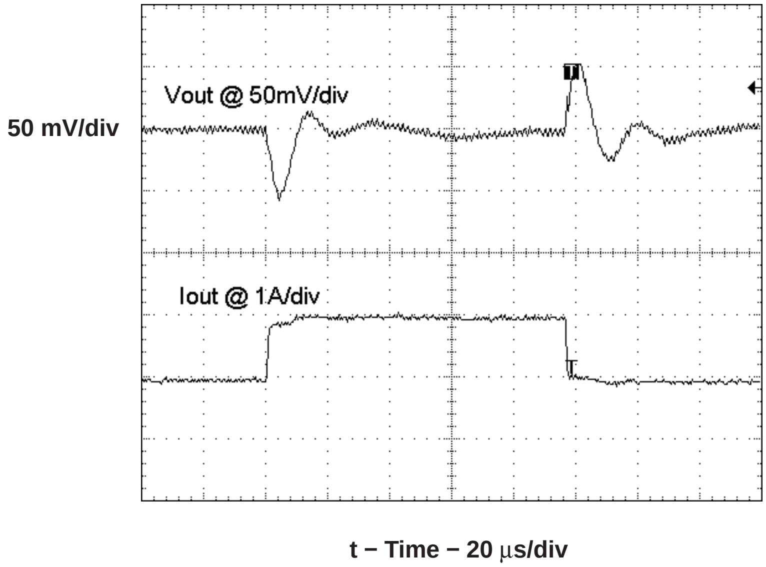


Figure 10.

7 PCB Layout

Figures 11 through13 show the top copper layer, the bottom copper layer, and top assembly layer, of HPA069.

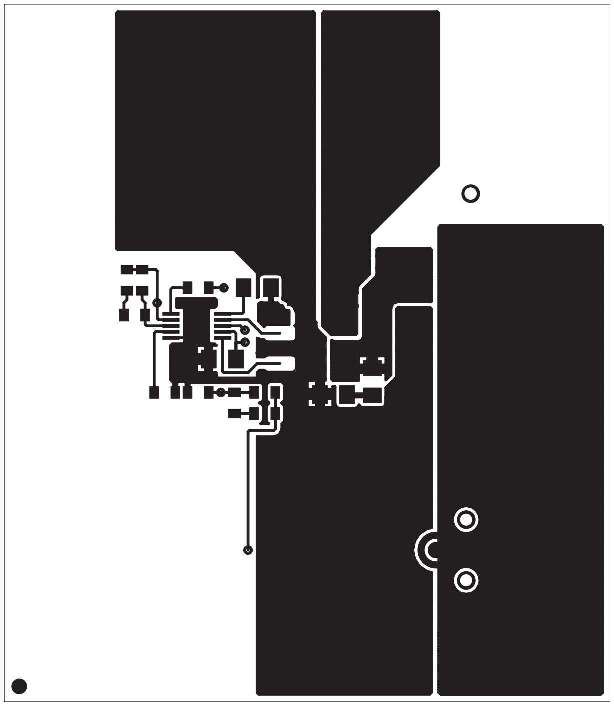


Figure 11

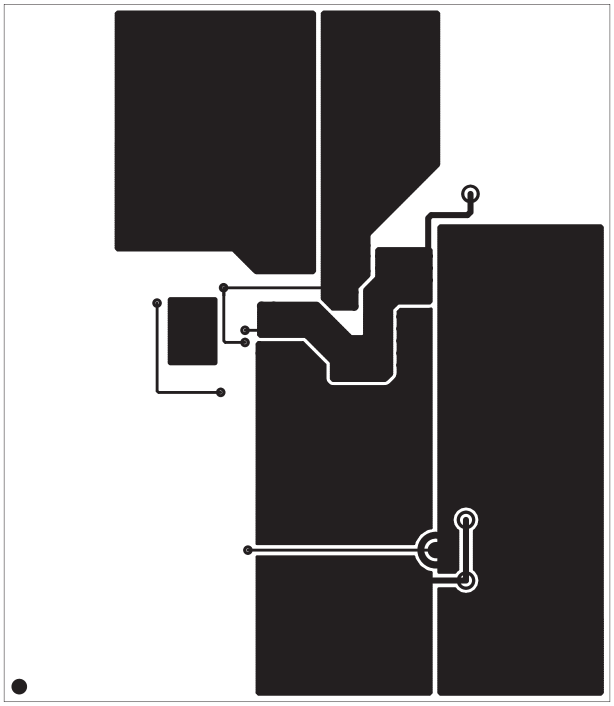
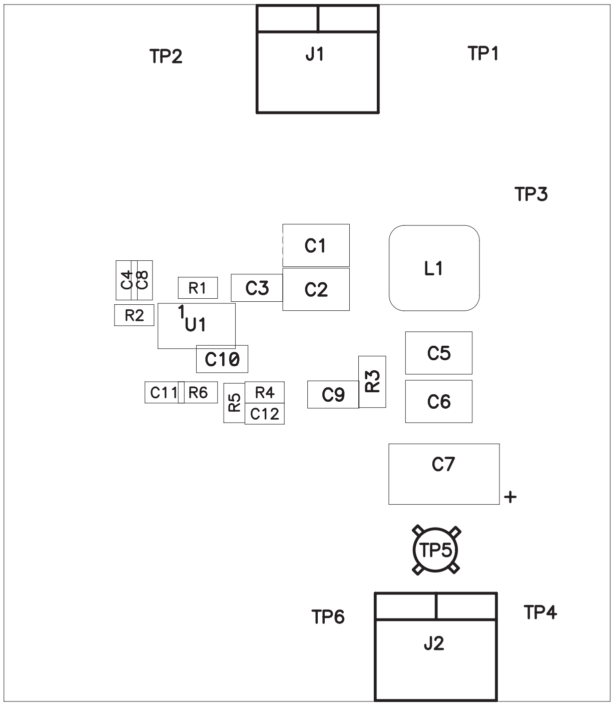
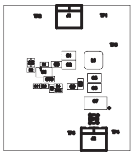


Figure 12





actual size

Figure 13

8 List of Material

Table 1 lists the components used in this design. With minor component tweaks this design could be modified to meet a wide range of applications.

	Reference	Qty	Description	Manufacturer	Part Number
Capacitor	C1, C2, C5, C6	4	Ceramic, 22 µF, 6.3 V, X5R, 20%, 1210	Panasonic	ECJ−4YB0J226M
	C10	1	Ceramic, 0.001 µF, 10 V, X5R, 10%, 805	Panasonic	ECJ−2YB1A105K
	C11	1	Ceramic, 0.0047 µF, 50 V, X7R, 10%	Vishay	VJ0603Y472KXAAT
	C12	1	Ceramic, 470 pF, 50 V, X7R, 10%	Vishay	VJ0603Y471KXAAT
	C3	1	Ceramic, 0.1 µF, 50 V, X5R, 10%	Vishay	VJ0805Y104KXAAT
	C4	1	Ceramic, 0.001 µF, 50 V, X7R, 10%	Vishay	VJ0603Y102KXAAT
	C8	1	Ceramic, 68 pF, 50 V, NPO, 10%	Vishay	VJ0603A680KXAAT
	C9	1	Ceramic, 0.0033 µF, 50 V, X7R, 10%	Vishay	VJ0805Y332KXAAT
Terminal Block	J1, J2	2	2 pin, 15 A, 5.1 mm	OST	ED1609
Inductor	L1	1	SMT, 1.0 µH, 8.5 A, 10 mΩ	Vishay	IHLP−2525CZ−01
MOSFET	Q1	1	Dual N−channel, 20 V, 9.4 A, 18 mΩ	Fairchild	FDS6898A
Resistor	R1	1	Chip, 15 kΩ, 1/16W, 1%	Std	Std
	R2	1	Chip, 8.66 kΩ, 1/16 W, 1%	Std	Std
	R3	1	Chip, 2.2 Ω, 1/10 W, 5%	Std	Std
	R4	1	Chip, 12.1 kΩ, 1/16 W, 1%	Std	Std
	R5	1	Chip, 1 kΩ, 1/16 W, 1%	Std	Std
	R6	1	Chip, 16.9 Ω, 1/16 W, 1%	Std	Std
JACK	TP1, TP3, TP4,	5	Test point, red	Farnell	240−345
JACK	TP2, TP6	2	Test point, black	Farnell	240−333
Adaptor	TP5	1	3.5-mm probe clip (or 131−5031−00)	Tektronix	131−4244−00
Device	U1	1	Syncronous buck controller, 600 kHz	TI	TPS40009DGQ

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。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス·インスツルメンツ株式会社
東京都新宿区西新宿６丁目２４番１号
西新宿三井ビル

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

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025