

Evaluation Module for TPS54061 Synchronous Step-Down SWIFT

This user's guide contains information for the TPS54061EVM-142 evaluation module (PWR142) including the performance specifications, the schematic, and the bill of materials.

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1 Introduction

This user's guide contains background information for the TPS54061 as well as support documentation for the TPS54061EVM-142 evaluation module (PWR142). Also included are the performance specifications, the schematic, and the bill of materials for the TPS54061EVM-142.

1.1 Background

The TPS54061 dc/dc converter is designed to provide up to a 0.2A output from an input voltage source of 4.7V to 60V. Rated input voltage and output current range for the evaluation module are given in [Table 1](#). This evaluation module is designed to demonstrate the small, printed-circuit-board areas that may be achieved when designing with the TPS54061 regulator. The switching frequency is externally set at a nominal 400 kHz. The high-side and low-side MOSFETs are incorporated inside the TPS54061 package along with the gate drive circuitry. The compensation components are external to the integrated circuit (IC), and an external divider allows for an adjustable output voltage. Additionally, the TPS54061 provides undervoltage lockout inputs. The absolute maximum input voltage is 60V for the TPS54061EVM-142.

Table 1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS54061EVM-142	$V_{IN} = 8V$ to 60V	0 A to 0.2A

1.2 Performance Specification Summary

A summary of the TPS54061EVM-142 performance specifications is provided in [Table 2](#). Specifications are given for an input voltage of $V_{IN} = 24V$ and an output voltage of 3.3V, unless otherwise specified. The TPS54061EVM-142 is designed and tested for $V_{IN} = 8V$ to 60V. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 2. TPS54061EVM-142 Performance Specification Summary

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN} voltage range		8	24	60	V
Output voltage set point			3.3		V
Output current range	$V_{IN} = 8V$ to 60V	0		0.2	A
Line regulation	$I_O = 0.2A$, $V_{IN} = 8V$ to 60V		±0.2%		
Load regulation	$V_{IN} = 24V$, $I_O = 0.001A$ to 0.2A		±0.1%		
Load transient response	$I_O = 0.05A$ to 0.15A	Voltage change	-75		mV
		Recovery time	1		ms
	$I_O = 0.15A$ to 0.05A	Voltage change	75		mV
		Recovery time	1		ms
Loop bandwidth	$V_{IN} = 24V$, $I_O = 0.2A$		11		kHz
Phase margin	$V_{IN} = 24V$, $I_O = 0.2A$		77		°
Input ripple voltage	$I_O = 0.2A$		50		mVpp
Output ripple voltage	$I_O = 0.2A$		6		mVpp
Output rise time			4		ms
Operating frequency			400		kHz
Maximum efficiency	TPS54061EVM-142, $V_{IN} = 8V$, $I_O = 0.07A$		90.4%		
DCM threshold	$V_{IN} = 24V$		35		mA
Skip threshold	$V_{IN} = 24V$		5.5		mA
No load input current	$V_{IN} = 24V$		260		µA
UVLO start threshold			7.5		V
UVLO stop threshold			6.5		V

1.3 Modifications

These evaluation modules are designed to provide access to the features of the TPS54061. Some modifications can be made to this module.

1.3.1 Output Voltage Set Point

To change the output voltage of the EVM, it is necessary to change the value of resistor R_6 . Changing the value of R_6 can change the output voltage above 0.8V. The value of R_6 for a specific output voltage can be calculated using [Equation 1](#).

$$R_6 = 10 \text{ k}\Omega \times \frac{(V_{\text{OUT}} - 0.8 \text{ V})}{0.8 \text{ V}} \quad (1)$$

[Table 3](#) lists the R_6 values for some common output voltages. Note that V_{IN} must be in a range so that the minimum on-time is greater than 120ns. The values given in [Table 3](#) are standard values, not the exact value calculated using [Equation 1](#).

Table 3. Output Voltages Available

Output Voltage (V)	R_6 Value (k Ω)
1.8	12.7
2.5	21.5
3.3	31.6
5	52.3

Be aware that changing the output voltage can affect the loop response. It may be necessary to modify the compensation components. See the data sheet for details.

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54061EVM-142 evaluation module. The section also includes test results typical for the evaluation module and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

2.1 Input/Output Connections

The TPS54061EVM-142 is provided with input/output connectors and test points as shown in [Table 4](#). A power supply capable of supplying 0.2A must be connected to J1 through a pair of 20 AWG wires. The load must be connected to J2 through a pair of 20 AWG wires. The maximum load current capability must be 0.2A. Wire lengths must be minimized to reduce losses in the wires. Test-point TP1 provides a place to monitor the V_{IN} input voltages with TP2 providing a convenient ground reference. TP5 is used to monitor the output voltage with TP6 as the ground reference.

Table 4. EVM Connectors and Test Points

Reference Designator	Function
J1	V_{IN} (see Table 1 for V_{IN} range).
J2	V_{OUT} , 3.3V at 0.2A maximum.
JP1	EN jumper. Connect EN to ground to disable, open to enable.
TP1	V_{IN} test point at V_{IN} connector.
TP2	GND test point at V_{IN} .
TP3	PH test point.
TP4	Test point between voltage divider network and output. Used for loop response measurements.
TP5	Output voltage test point at OUT connector.
TP6	GND test point at OUT connector.

2.2 Efficiency

The efficiency of this EVM peaks at a load current of about 0.07A with $V_{IN} = 8V$, and then decreases as the load current increases towards full load. Figure 1 shows the efficiency for the TPS54061EVM-142 at an ambient temperature of 25°C.

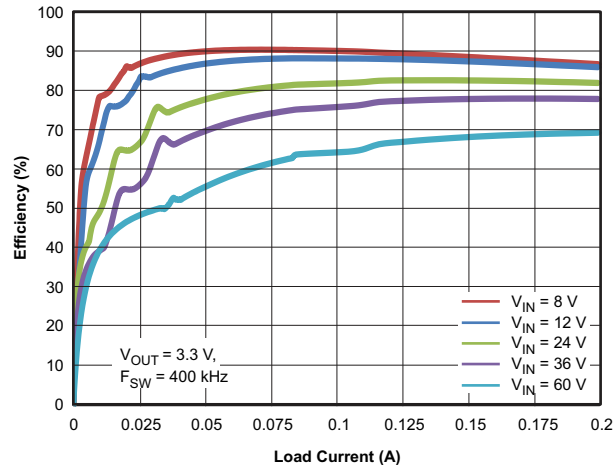


Figure 1. TPS54061EVM-142 Efficiency

Figure 2 shows the efficiency for the TPS54061EVM-142 at lower output currents between 0.001A and 0.2A at an ambient temperature of 25°C.

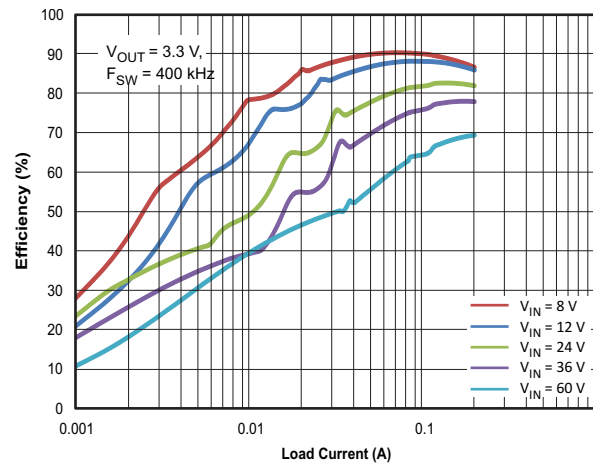


Figure 2. TPS54061EVM-142 Low Current Efficiency

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

2.3 Output Voltage Load Regulation

The load regulation for the TPS54061EVM-142 is shown in Figure 3.

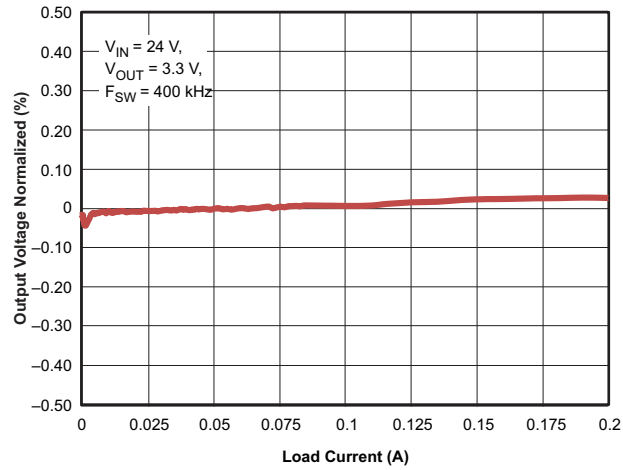


Figure 3. TPS54061EVM-142 Load Regulation

Measurements are given for an ambient temperature of 25°C.

2.4 Output Voltage Line Regulation

The line regulation for the TPS54061EVM-142 is shown in Figure 4.

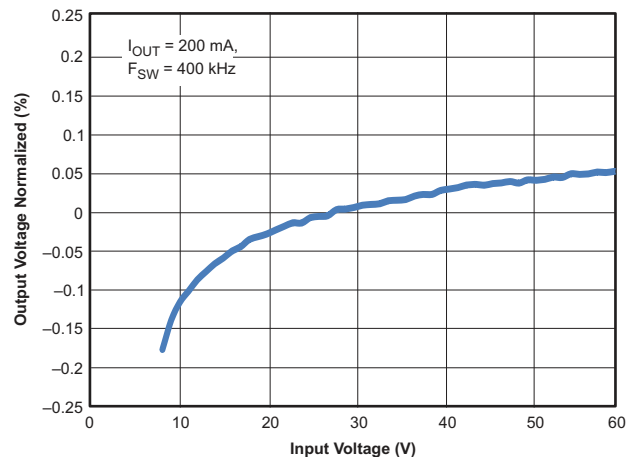


Figure 4. TPS54061EVM-142 Line Regulation

2.5 Load Transients

The TPS54061EVM-142 response to load transients is shown in Figure 5. The current step is from 25% to 75% of maximum rated load at 24V input. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

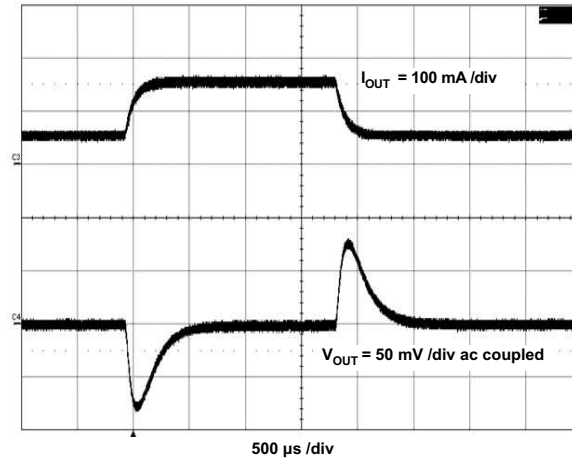


Figure 5. TPS54061EVM-142 Load Transient Response

2.6 Line Transients

The TPS54061EVM-142 response to line transients is shown in Figure 6. The input voltage step is from 10V to 40V. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

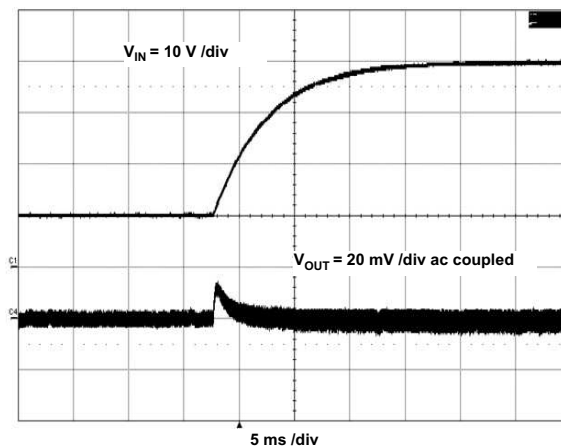


Figure 6. TPS54061EVM-142 Line Transient Response

2.7 Loop Characteristics

The TPS54061EVM-142 loop-response characteristics are shown in Figure 7 . Gain and phase plots are shown for V_{IN} voltage of 24V. Load current for the measurement is 0.2A.

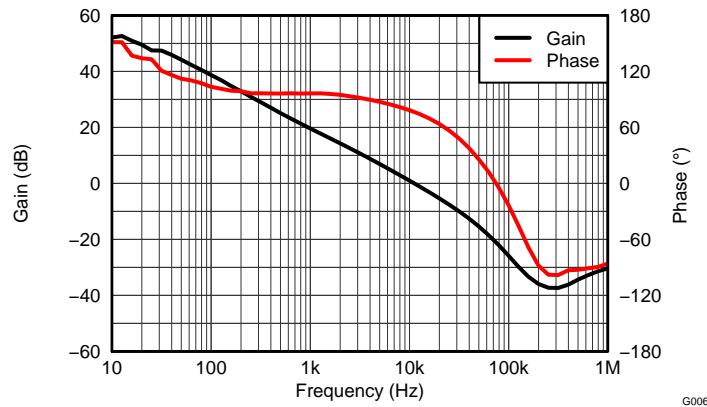


Figure 7. TPS54061EVM-142 Loop Response

2.8 Output Voltage Ripple

The TPS54061EVM-142 CCM output voltage ripple is shown in Figure 8 . The output current is the rated full load of 0.2A and $V_{IN} = 24V$. The ripple voltage is measured directly across the output capacitors.

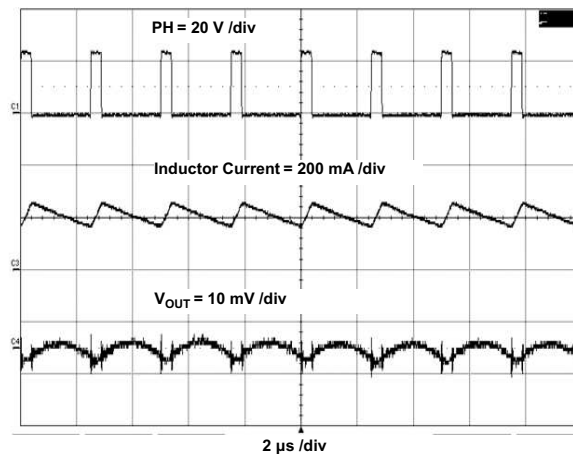


Figure 8. TPS54061EVM-142 Output Ripple CCM

The TPS54061EVM-142 DCM output voltage ripple is shown in Figure 9 . The output current is 0.02A and $V_{IN} = 24V$. The ripple voltage is measured directly across the output capacitors.

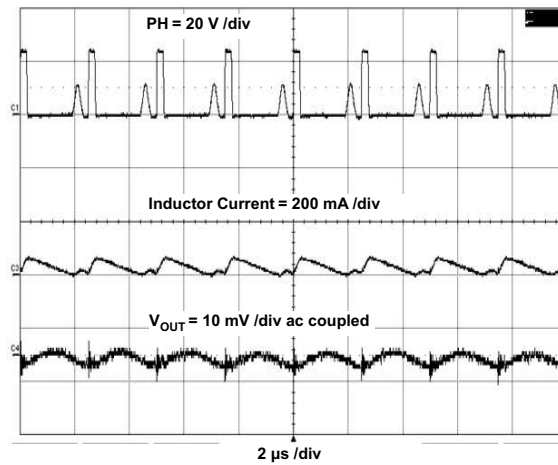


Figure 9. TPS54061EVM-142 Output Ripple DCM

The TPS54061EVM-142 skip mode output voltage ripple is shown in Figure 10 . The output current is less than .002A and $V_{IN} = 24\text{V}$. The ripple voltage is measured directly across the output capacitors.

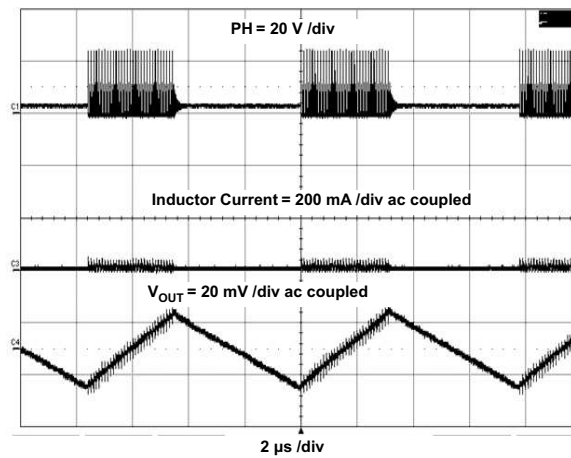


Figure 10. TPS54061EVM-142 Output Ripple Skip Mode

2.9 Input Voltage Ripple

The TPS54061EVM-142 CCM input voltage ripple is shown in [Figure 11](#) . The output current is the rated full load of 0.2A and $V_{IN} = 24V$. The ripple voltage is measured directly across the input capacitors.

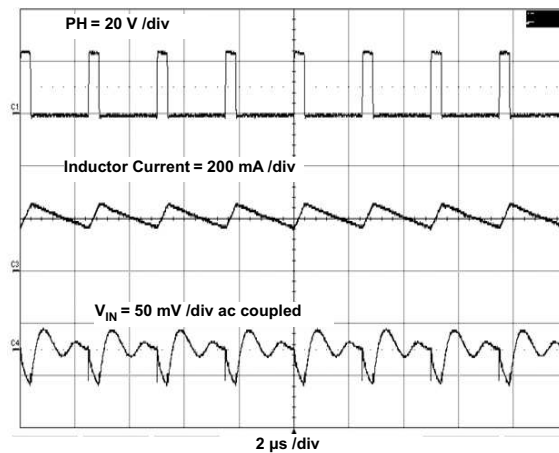


Figure 11. TPS54061EVM-142 Input Ripple CCM

The TPS54061EVM-142 DCM input voltage ripple is shown in [Figure 12](#) . The output current is 0.02A and $V_{IN} = 24V$. The ripple voltage is measured directly across the input capacitors.

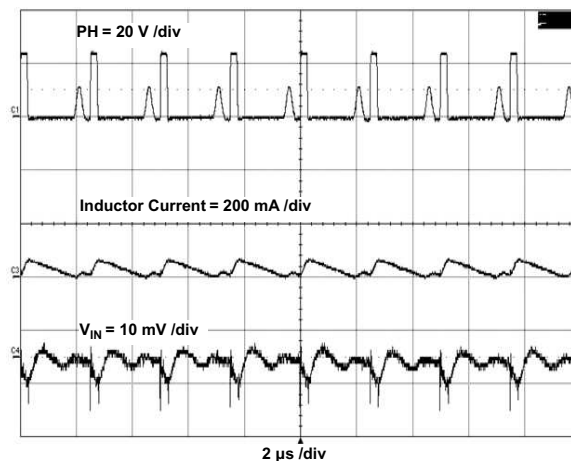


Figure 12. TPS54061EVM-142 Input Ripple DCM

The TPS54061EVM-142 skip-mode, input-voltage ripple is shown in [Figure 13](#) . The output current is less than 0.002A and $V_{IN} = 24V$. The ripple voltage is measured directly across the input capacitors.

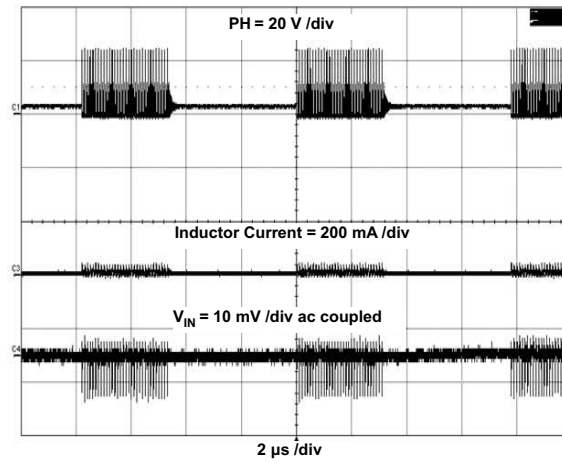


Figure 13. TPS54061EVM-142 Input-Ripple Skip Mode

2.10 Powering Up

The start-up waveforms are shown in [Figure 14](#) and [Figure 15](#). In [Figure 14](#), the top trace shows V_{IN} , the middle trace shows EN, and the bottom trace shows V_{OUT} . The input voltage is initially applied, and when the input reaches the undervoltage lockout threshold, the start-up sequence begins and the output ramps up at the externally set rate toward the set value of 3.3V. The input voltage for these plots is 24V with a 16Ω resistive load.

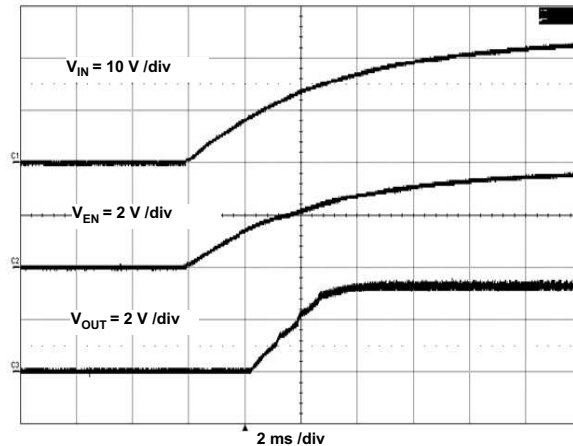


Figure 14. TPS54061EVM-142 Start-Up Relative to V_{IN}

In [Figure 15](#), the top trace shows V_{IN} , the middle trace shows EN, and the bottom trace shows V_{OUT} . The input voltage is initially applied with EN held low. When EN is released, the start-up sequence begins and the output ramps up at the externally set rate toward the set value of 3.3 V. The input voltage for these plots is 24 V with a 16Ω resistive load.

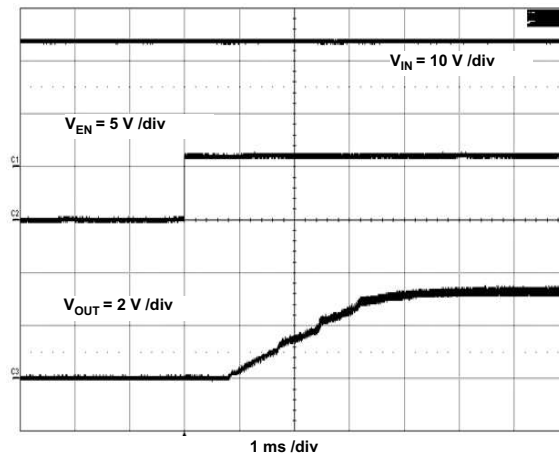


Figure 15. TPS54061EVM-142 Start-Up Relative to EN

2.11 Powering Down

The shutdown waveforms are shown in [Figure 16](#) and [Figure 17](#). In [Figure 16](#), the top trace shows V_{IN} , the middle trace shows EN, and the bottom trace shows V_{OUT} . The input voltage is removed, and when the input falls below the undervoltage lockout threshold, the TPS54061 shuts down and the output falls to ground. The input voltage for these plots is 24V with a 16 Ω resistive load.

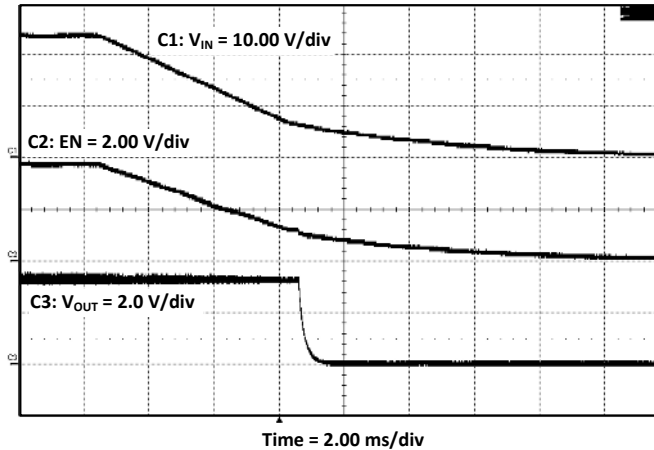


Figure 16. TPS54061EVM-142 Shutdown Relative to V_{IN}

In [Figure 17](#), the top trace shows V_{IN} , the middle trace shows EN, and the bottom trace shows V_{OUT} . The input voltage is held at 24V, and EN is shorted to ground. When EN is grounded, the TPS54061 is disabled, and the output voltage discharges to ground. The input voltage for these plots is 24V with a 16 Ω resistive load.

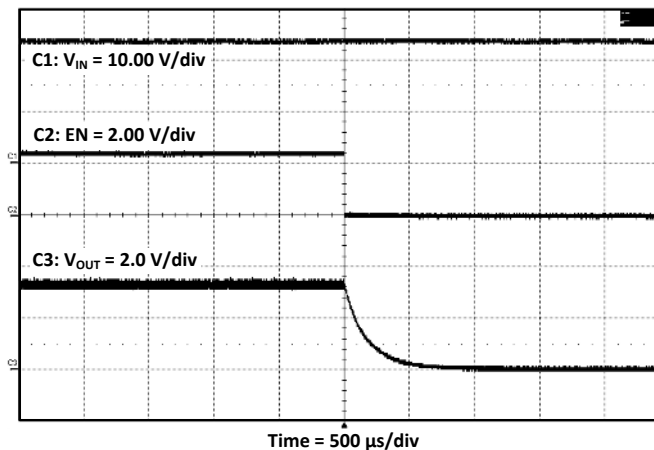


Figure 17. TPS54061EVM-142 Shutdown Relative to EN

3 Board Layout

This section provides a description of the TPS54061EVM-142, board layout, and layer illustrations.

3.1 Layout

The board layout for the TPS54061EVM-142 is shown in [Figure 18](#) through [Figure 20](#). The top-side layer of the EVM is laid out in a manner typical of a user application. The top and bottom layers are 2-oz copper.

The top layer contains the main power traces for V_{IN} , V_{OUT} , and V_{PHASE} . Also on the top layer are connections for the remaining pins of the TPS54061 and a large area filled with ground. The bottom layer contains ground and a signal route for the BOOT capacitor. The top and bottom and internal ground traces are connected with multiple vias placed around the board including four vias directly under the TPS54061 device to provide a thermal path from the top-side ground plane to the bottom-side ground plane.

The input decoupling capacitors (C2 and C3), bootstrap capacitor (C4), and frequency set resistor (R3) are all located as close to the IC as possible. In addition, the voltage set-point resistor divider components are also kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation, the copper V_{OUT} trace past the output connector (J2). For the TPS54061, an additional input bulk capacitor may be required (C1), depending on the EVM connection to the input supply.

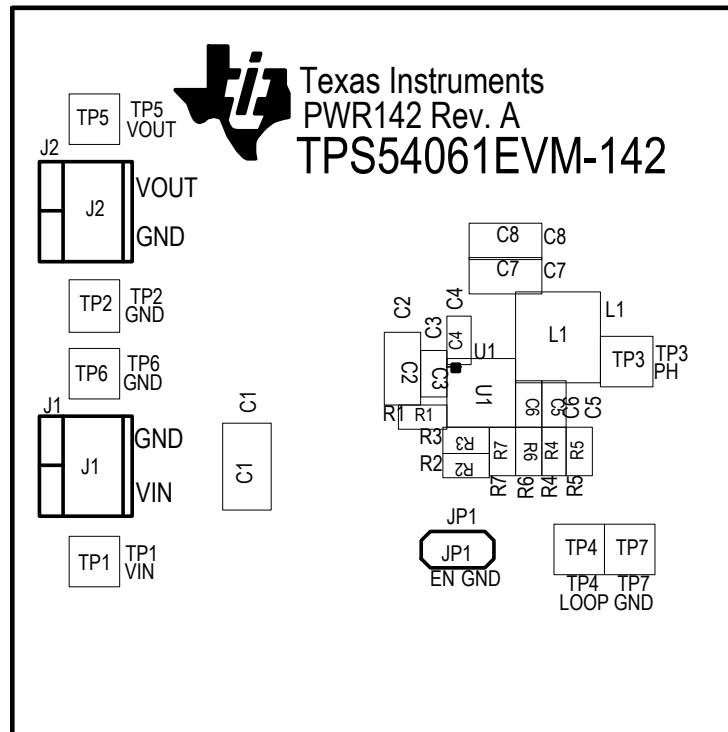


Figure 18. TPS54061EVM-142 Top Assembly and Silkscreen

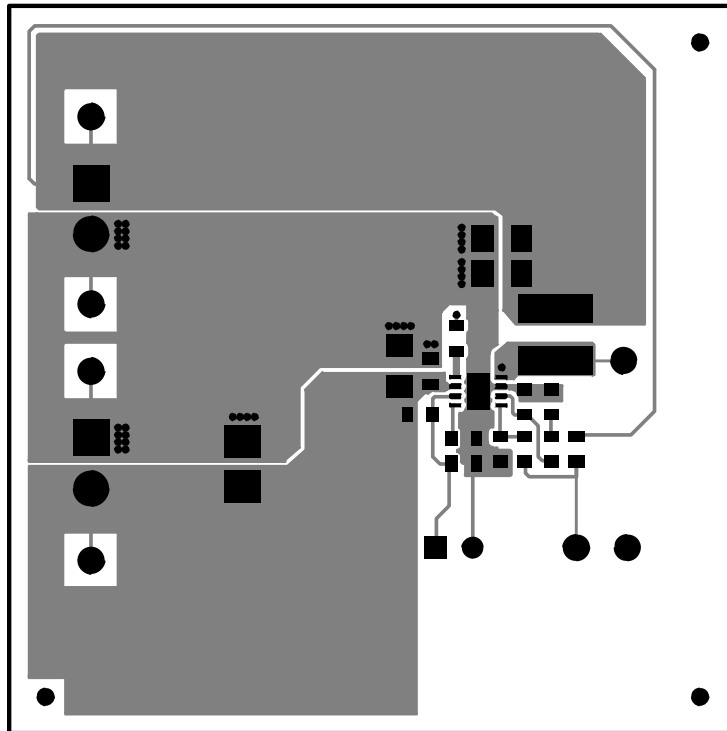


Figure 19. TPS54061EVM-142 Top-Side Layout

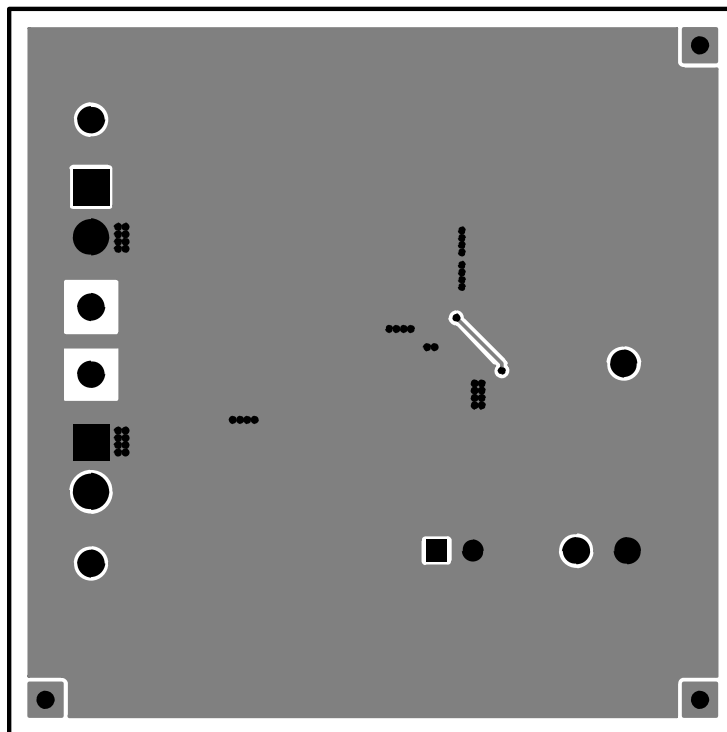


Figure 20. TPS54061EVM-142 Bottom-Side Assembly

3.2 Estimated Circuit Area

The estimated printed-circuit-board area for the components used in this design is 0.214 in² (140 mm²). This area does not include test points or connectors. This design uses 0603 components for easy modifications. The area can be reduced by using smaller sized components.

4 Schematic and Bill of Materials

This section presents the TPS54061EVM-142 schematic and bill of materials.

4.1 Schematic

Figure 21 is the schematic for the TPS54061EVM-142.

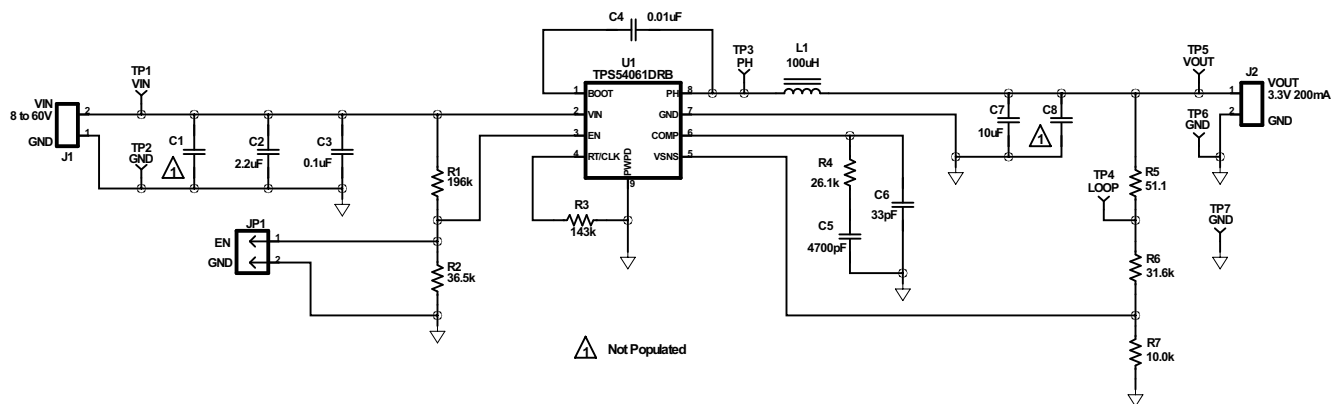


Figure 21. TPS54061EVM-142 Schematic

4.2 Bill of Materials

Table 5 presents the bill of materials for the TPS54061EVM-142.

Table 5. TPS54061EVM-142 Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
0	C1	Open	Capacitor, Ceramic, 100V, X7R, 10%	Multi sizes	Engineering Only	Std
1	C2	2.2 μ F	Capacitor, Ceramic, 100V, X7S, 20%	1206	Std	Std
1	C3	0.1 μ F	Capacitor, Ceramic, 100V, X7R, 10%	0603	Std	Std
1	C4	0.01 μ F	Capacitor, Ceramic, 10V, X5R, 10%	0603	Std	Std
1	C5	4700pF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
1	C6	33pF	Capacitor, Ceramic, 50V, NP0, 10%	0603	Std	Std
1	C7	10 μ F	Capacitor, Ceramic, 10V, X5R, 5%	1206	Std	Std
0	C8	Open	Capacitor, Ceramic	1206	Std	Std
2	J1, J2	ED1514	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25"	ED555/2DS	OST
1	JP1	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (02-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
1	L1	100 μ H	Inductor, SMT, 0.52A, 0.77ohm	4838	74408943101	WE
1	R1	196k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	R2, R6	36.5k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	143k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R4	26.1k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	51.1	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R7	10.0k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
4	TP1, TP3, TP4, TP5	5000	Test Point, Red, Thru Hole Color Keyed	0.100 x 0.100 inch	5000	Keystone
3	TP2, TP6, TP7	5001	Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	5001	Keystone
1	U1	TPS54061DRB	IC, Synchronous Buck Regulator, 60V, 200 mA	QFN	TPS54061DRB	TI
1	-		PCB, 3 in. x 3 in. x 0.062 in		PWR142	Any

- Notes:
1. These assemblies are ESD sensitive, ESD precautions shall be observed.
 2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.
 3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.
 4. Ref designators marked with an asterisk (***) cannot be substituted. All other components can be substituted with equivalent MFG's components.

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

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.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED 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. 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.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

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REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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(address) 24-1, Nishi-Shinjuku 6 chome, Shinjuku-ku, Tokyo, Japan

<http://www.tij.co.jp>

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2. 実験局の免許を取得後ご使用いただく。
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東京都新宿区西新宿6丁目24番1号
西新宿三井ビル

<http://www.tij.co.jp>

EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. 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 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

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.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED 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. 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.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

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REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

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2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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【ご使用にあたっての注】

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2. 実験局の免許を取得後ご使用いただく。
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東京都新宿区西新宿6丁目24番1号
西新宿三井ビル

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EVALUATION BOARD/KIT/MODULE (EVM) WARNINGS, RESTRICTIONS AND DISCLAIMERS

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Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. 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 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

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