

AN-2065 LM5119 Evaluation Board

1 Introduction

The LM5119EVAL evaluation board provides the design engineer with a fully functional dual output buck converter, employing the LM5119 Dual Emulated Current Mode Synchronous Buck Controller. The evaluation board is designed to provide both 10V and 5V outputs over an input range of 14V to 55V. Also the evaluation board can be easily configured for a single 10V, 8A regulator.

2 Performance of the Evaluation Board

- Input Voltage Range: 14V to 55V
- Output Voltage: 10V (CH1), 5V (CH2)
- Output Current: 4A (CH1), 8A (CH2)
- Nominal Switching Frequency: 230 KHz
- Synchronous Buck Operation: Yes
- Diode Emulation Mode: Yes
- Hiccup Mode Overload Protection: Yes
- External VCC Sourcing: Yes

3 Powering and Loading Consideration

When applying power to the LM5119 evaluation board, certain precautions need to be followed. A misconnection can damage the assembly.

3.1 Proper Board Connection

The input connections are made to the J1 (VIN) and J2 (RTN/GND) connectors. The CH1 load is connected to the J3 (OUT1+) and J4 (OUT1-/GND) and the CH2 load is connected to the J6 (OUT2+) and J5 (OUT2-/GND). Be sure to choose the correct connector and wire size when attaching the source power supply and the load.

3.2 Source Power

The power supply and cabling must present low impedance to the evaluation board. Insufficient cabling or a high impedance power supply will droop during power supply application with the evaluation board inrush current. If large enough, this droop will cause a chattering condition during power up. During power down, insufficient cabling or a high impedance power supply will overshoot. This overshoot will cause a non-monotonic decay on the output.

An additional external bulk input capacitor may be required unless the output voltage droop/overshoot of the source power is less than 0.7V. In this board design, UVLO setting is conservative while UVLO hysteresis setting is aggressive. Minimum input voltage can go down with an aggressive design. Minimum operating input voltage depends on the output voltage droop/overshoot of the source power supply and the forced off-time of the LM5119. For complete design information, see the *LM5119/LM5119Q Wide Input Range Dual Synchronous Buck Controller Data Sheet* ([SNVS676](#)).

3.3 Loading

When using an electronic load, it is strongly recommended to power up the evaluation board at light load and then slowly increase the load. If it is desired to power up the evaluation board at maximum load, resistor banks must be used. In general, electronic loads are best suited for monitoring steady state waveforms.

3.4 Air Flow

Prolonged operation with high input voltage at full power will cause the MOSFETs to overheat. A fan with a minimum of 200LFM should be always provided.

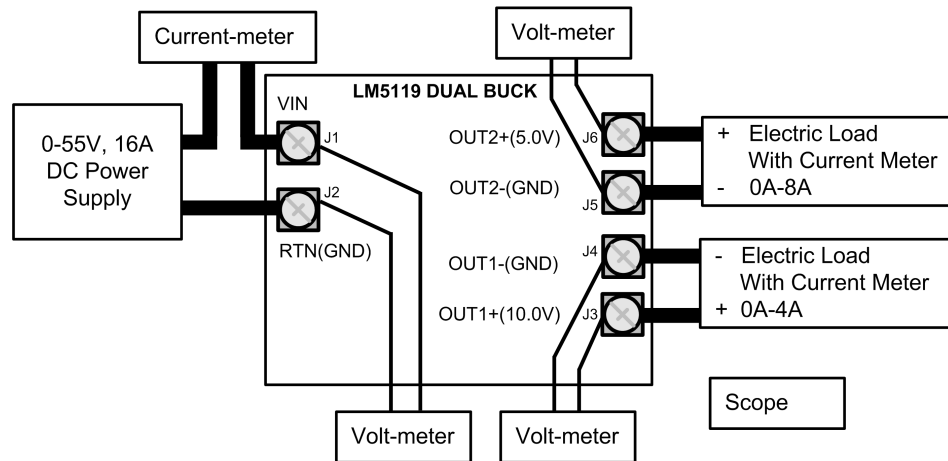


Figure 1. Typical Evaluation Setup

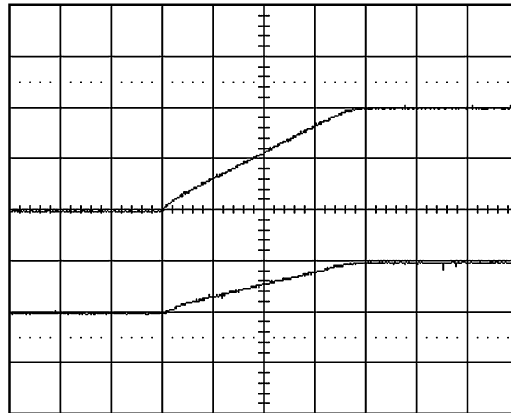
3.5 Quick Start-Up Procedure

1. Set the power supply current limit to at least 16A. Connect the power supply to J1 and J2.
2. Connect one load with a 4A capacity between J3 and J4. Connect another load with an 8A capacity between J6 and J5.
3. Set input voltage to 24V and turn it on.
4. Measure the output voltages. CH1 should regulate at 10V and CH2 should regulate at 5V.
5. Slowly increase the load current while monitoring the output voltages. The outputs should remain in regulation up to full load current.
6. Slowly sweep the input voltage from 14V to 55V while monitoring the output voltages. The outputs should remain in regulation.

4 Waveforms

4.1 Soft Start

When applying power to the LM5119 evaluation board a certain sequence of events occurs. Soft-start capacitors and other components allow for a linear increase in output voltages. The soft-start time of each output can be controlled independently. [Figure 2](#) shows the output voltage during a typical start-up with a load of 3Ω on the 10V output, and 1Ω on the 5V output, respectively.



Conditions:

Input Voltage = 24VDC

3Ω Load on 10V output

1Ω Load on 5V output

Traces:

Top Trace: 10V Output Voltage, Volt/div = 5V

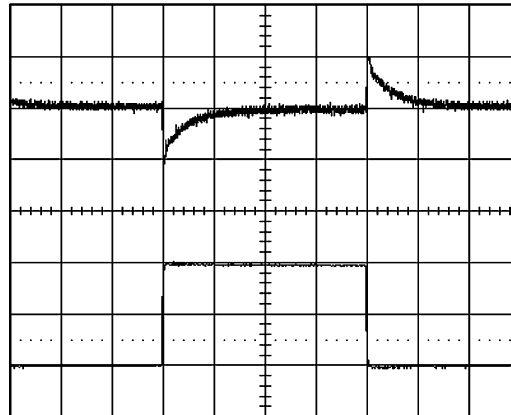
Bottom Trace: 5V Output Voltage, Volt/div = 5V

Horizontal Resolution = 1 ms/div

Figure 2. Start-Up With Resistive Load

4.2 Load Transient

Figure 3 shows the transient response for a load change from 2A to 6A on 5V output. The upper waveform shows output voltage droop and overshoot during the sudden change in output current shown by the lower waveform.



Conditions:

Input Voltage = 24VDC

Output Current 2A to 6A

Traces:

Top Trace: 5V Output Voltage, Volt/div = 100mV, AC coupled

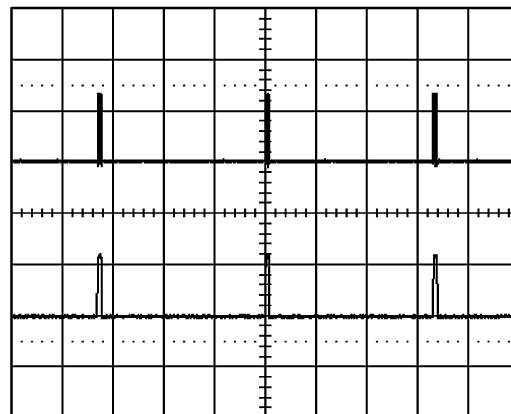
Bottom Trace: Output Current, Amp/div = 2A

Horizontal Resolution = 0.5 ms/div

Figure 3. Load Transient Response

4.3 Overload Protection

The evaluation board is configured with hiccup mode overload protection. The restart time can be programmed by C11. Figure 4 shows hiccup mode operation in the event of an output short on CH2 output. One channel may operate in the normal mode while the other is in hiccup mode overload protection.



Conditions:

Input Voltage = 24VDC

Output Short on 5V

Traces:

Top Trace: SW Voltage on CH2, Volt/div = 20V

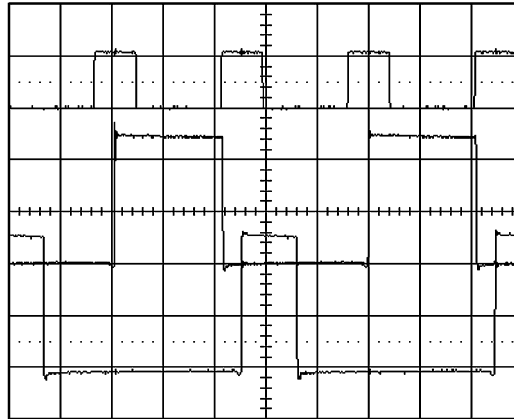
Bottom Trace: Inductor Current, Amp/div = 10A

Horizontal Resolution = 20 ms/div

Figure 4. Short Circuit

4.4 External Clock Synchronization

A TP1 (SYNC) test point has been provided on the evaluation board in order to synchronize the internal oscillator to an external clock. [Figure 5](#) shows the synchronized switching operation. Each channel operates 180° out of phase from the other.



Conditions:

Input Voltage = 24VDC
 4A on 10V Output
 8A on 5V Output

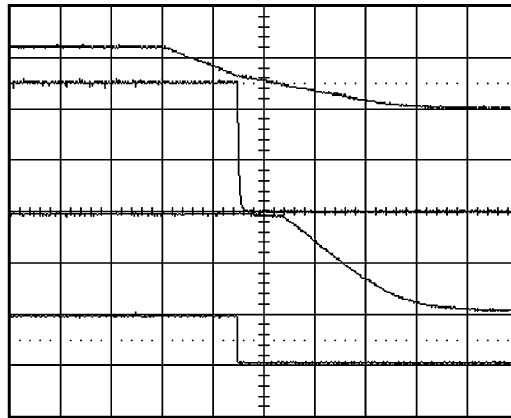
Traces:

Top Trace: SYNC pulse, Volt/div = 5V
 Middle Trace: SW voltage on CH1, Volt/div = 10V
 Bottom Trace: SW voltage on CH2, Volt/div = 10V
 Horizontal Resolution = 1 μ s/div

Figure 5. Clock Synchronization

4.5 Shutdown

Figure 6 shows the shutdown procedure by powering off the source power. When UVLO pin voltage is less than 1.26V, the switching stops and soft-start capacitors are discharged by internal switches.



Conditions:

Input Voltage = 24VDC
 1Ω Load on 5V Output

Traces:

Top Trace: Input Voltage, Volt/div = 20V
 Middle Trace1: 5V Output, Volt/div = 2V
 Middle Trace2: VCC, Volt/div = 5V
 Bottom Trace: SS Voltage, Volt/div = 5V
 Horizontal Resolution = 20 ms/div

Figure 6. Shutdown

5 Performance Characteristics

Figure 7 shows the efficiency curves. The efficiency of the power converter is 96% at 24V with full load current. Monitor the current into and out of the evaluation board. Monitor the voltage directly at the input and output terminals of the evaluation board.

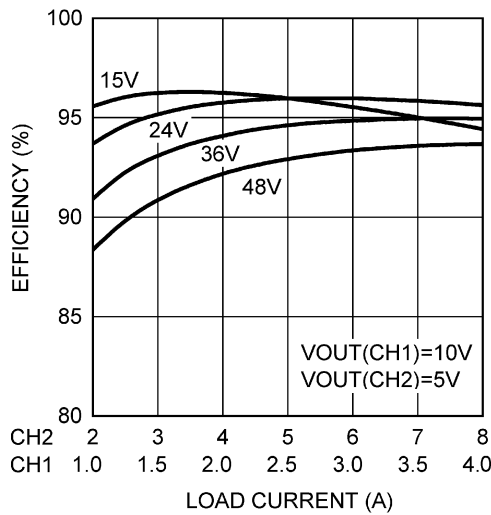


Figure 7. Typical Efficiency vs Load Current

6 Board Configuration

6.1 Interleaved Buck Operation for Single 10V 8A Output

The evaluation board is designed to be easily converted to a 10V, 8A single output regulator with the interleaved operation. Proper electronic load connection is shown in Figure 8. Connecting the electronic load at the center of shorting bar is recommended to prevent a voltage difference between CH1 and CH2 output. In order to produce a single 10V output with 8A maximum output current, populate R21 and R22 with 0Ω resistor and open R6, C15 and C14. The electronic load should have over 8A capability to test the interleaved operation.

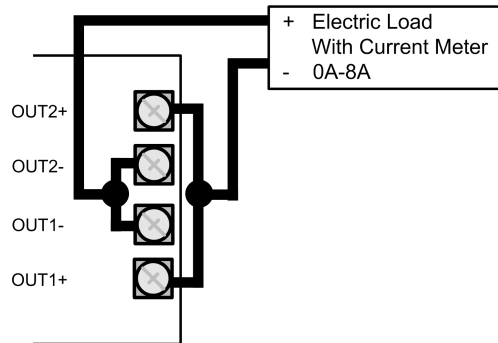


Figure 8. Load Connection for Single Output

6.2 External VCC Supply and VCC Disable

External VCC supply helps to reduce the temperature and the power loss of the LM5119 at high input voltage. By populating D3 and D4, VCC can be supplied from an external power supply. Use TP3 as an input of the external VCC supply with 0.1A current limit. R36, R35 and C45 should be populated with proper value when the voltage of the external VCC is smaller than 7V. The voltage at the VCCDIS pin can be monitored at TP2. To prevent a reverse current flow from VCC to VIN through the internal diode, the external VCC voltage should always be lower than VIN. In this LM5119 evaluation board, VCC1 and VCC2 are supplied from the 10V output to achieve high efficiency.

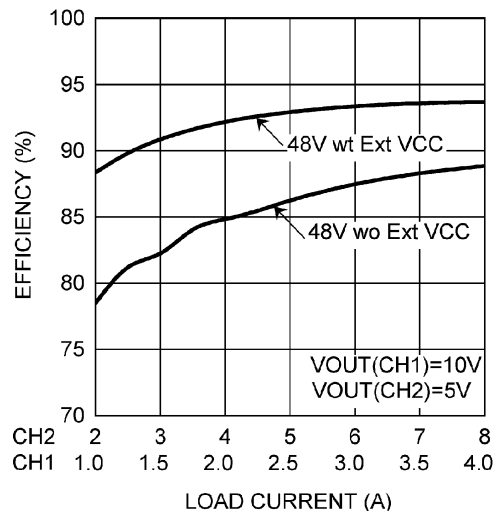


Figure 9. Efficiency Comparison at 48V With External VCC vs Without External VCC

6.3 Loop Response

TP5 and TP6 (TP7 and TP8) have been provided in order to measure the loop transfer function of CH1 (CH2). For detail information about the loop transfer function measurement, see *AN-1889 How to Measure the Loop Transfer Function of Power Supplies* ([SNVA364](#)).

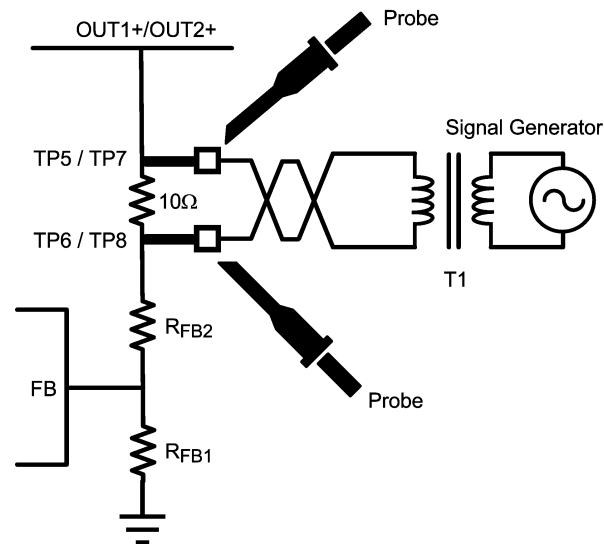
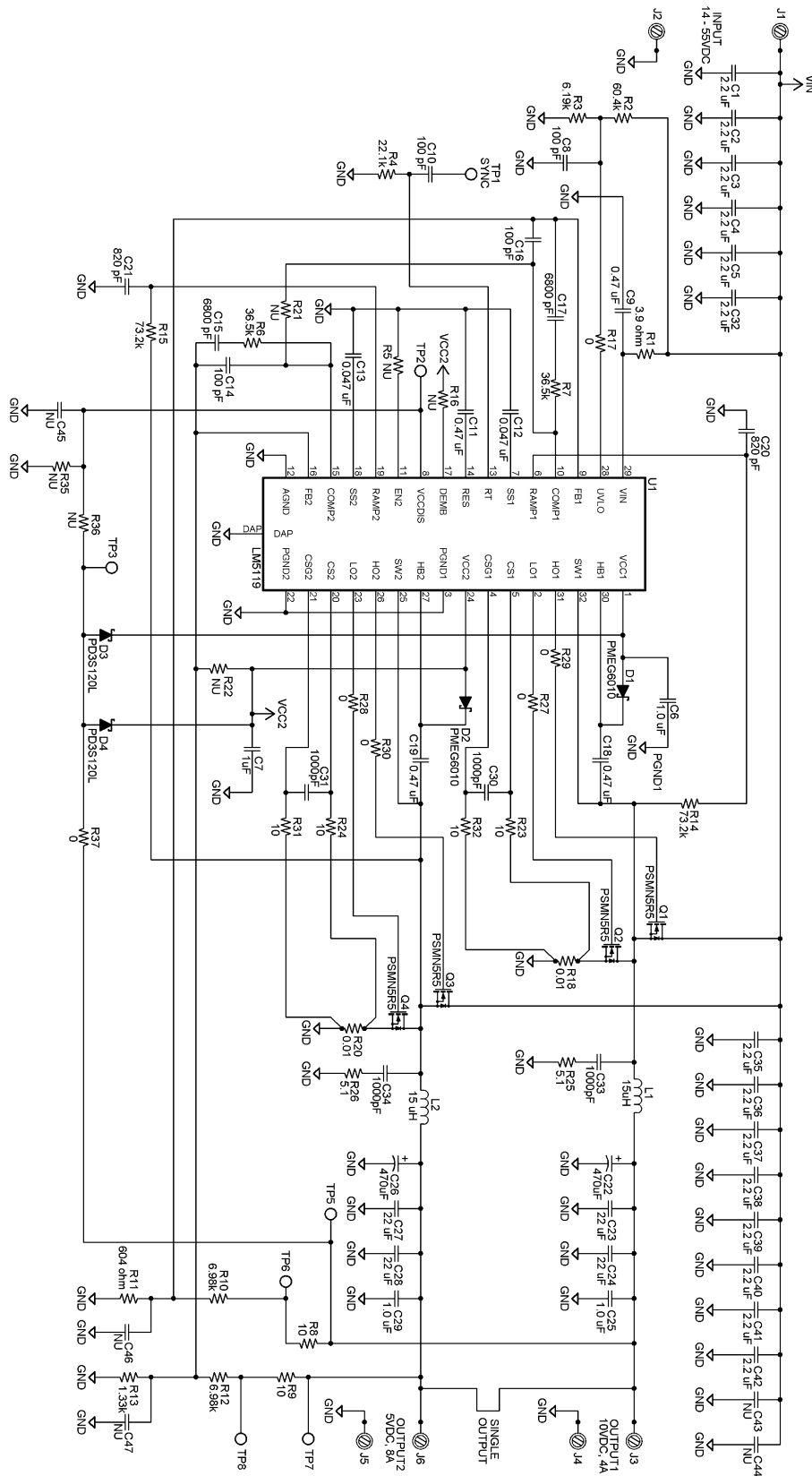


Figure 10. Loop Response Measurement Setup

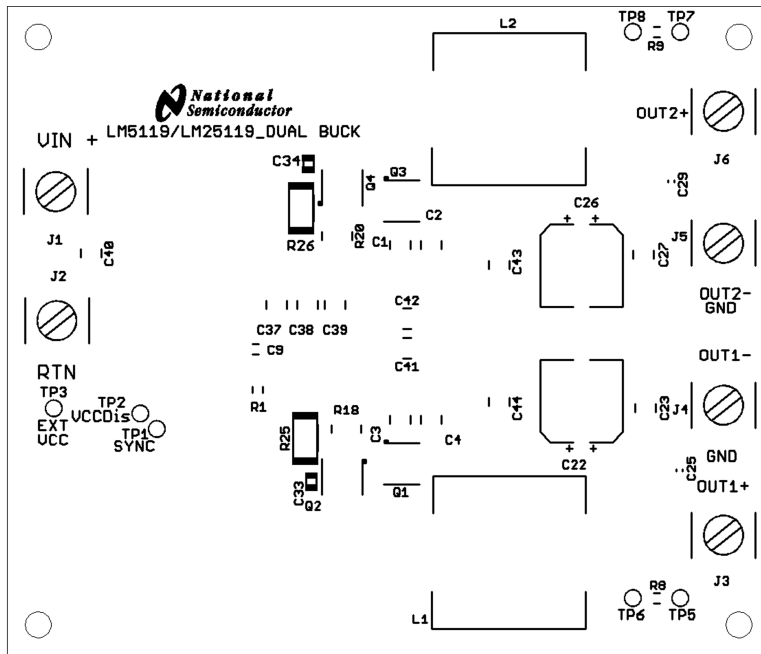
7 Evaluation Board Schematic



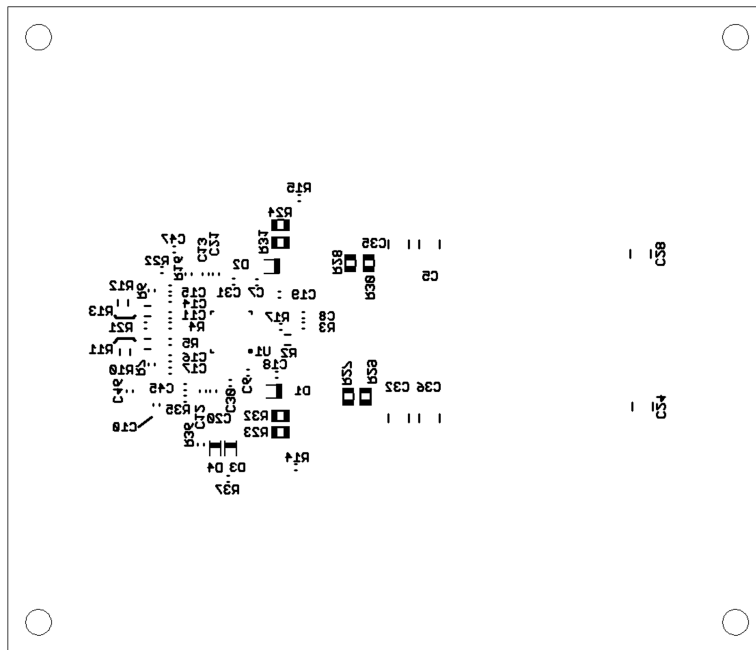
8 Bill of Materials (BOM)
Table 1. Bill of Materials (BOM)

Part	Value	Package	Part Number	Manufacturer
C1, C2, C3, C4,C5, C32, C35,C36, C37, C38, C39, C40, C41, C42	2.2 μ F, 100V, X7R	1210	C3225X7R2A225K	TDK
C6, C7, C25,C29	1 μ F, 16V, X7R	0603	C1608X7R1C105K	TDK
C8, C10, C14, C16	100pF, 50V, C0G	0603	C1608C0G1H101J	TDK
C9	0.47 μ F, 100V, X7R	0805	GRM21BR72A474KA73	Murata
C11, C18, C19	0.47 μ F, 25V, X7R	0603	GRM188R71E474KA12	Murata
C12,C13	0.047 μ F, 16V, X7R	0603	C1608X7R1C473K	TDK
C15,C17	6800pF, 25V, C0G	0603	C1608C0G1E682J	TDK
C20,C21	820pF, 50V, C0G	0603	C1608C0G1H821J	TDK
C22,C26	470 μ F, 16V	Φ 10	PCG1C471MCL1GS	Nichicon
C23,C24,C27,C28	22 μ F,16V, X7R	1210	C3225X7R1C226K	TDK
C30,C31	1000pF, 50V, X7R	0603	C1608X7R1H102K	TDK
C33,C34	1000pF,100V, C0G	0805	C2012C0G2A102J	TDK
C43,C44,C45,C46,C47	NU			
R1	3.9 ohm, 5%	0805	CRCW08053R90JNEA	Vishay
R2	60.4k, 1%	0805	CRCW080560K4FKEA	Vishay
R3	6.19k, 1%	0603	CRCW06036K19FKEA	Vishay
R4	22.1k, 1%	0603	CRCW060322K1FKEA	Vishay
R5,R16,R21,R22,R35,R36	NU			
R6,R7	36.5k, 1%	0603	CRCW060336K5FKEA	Vishay
R8,R9,R23,R24,R31, R32	10 ohm, 5%	0805	CRCW080510R0JNEA	Vishay
R10,R12	6.98k, 1%	0805	CRCW08056K98FKEA	Vishay
R11	604 ohm, 1%	0805	MCR10EZHf6040	Rohm
R13	1.33k, 1%	0805	MCR10EZHf1331	Rohm
R14,R15	73.2k, 1%	0603	CRCW060373K2FKEA	Vishay
R17,R37	0 ohm	0603	MCR03EzPJ000	Rohm
R18,R20	0.01 ohm, 1W, 1%	0815	RL3720WT-R010-F	Susumu
R25,R26	5.1 ohm, 1W, 1%	2512	ERJ-1TRQF5R1U	Panasonic — ECG
R27,R28,R29,R30	0 ohm	0805	MCR10EzPJ000	Rohm
D1,D2	60V, 1A	SOD123F	PMEG6010CEH	NXP
D3,D4	20V, 1A	PowerDI323	PD3S120L	Diodes
L1,L2	15 μ H, 14A	18.2x18.3	74435571500	WE
Q1,Q3, Q2,Q4	60V, 100A	LFPak SO-8	PSMN5R5-60YS	NXP
U1		WQFN32	LM5119	TI
J1,J2,J3,J4,J5,J6	15A		7693	Keystone
TP1,TP2,TP3		Φ 0.1	5002	Keystone
TP5,TP6,TP7,TP8			1040	Keystone

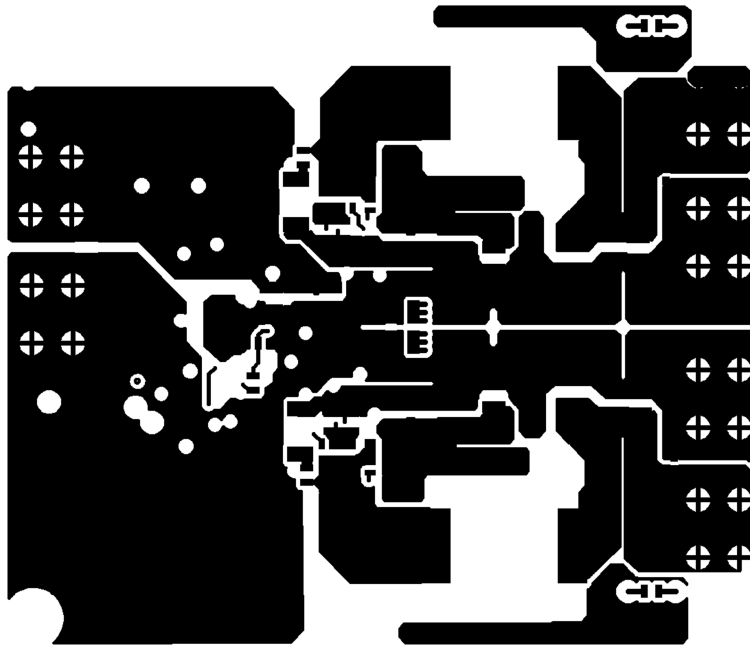
9 PCB Layout



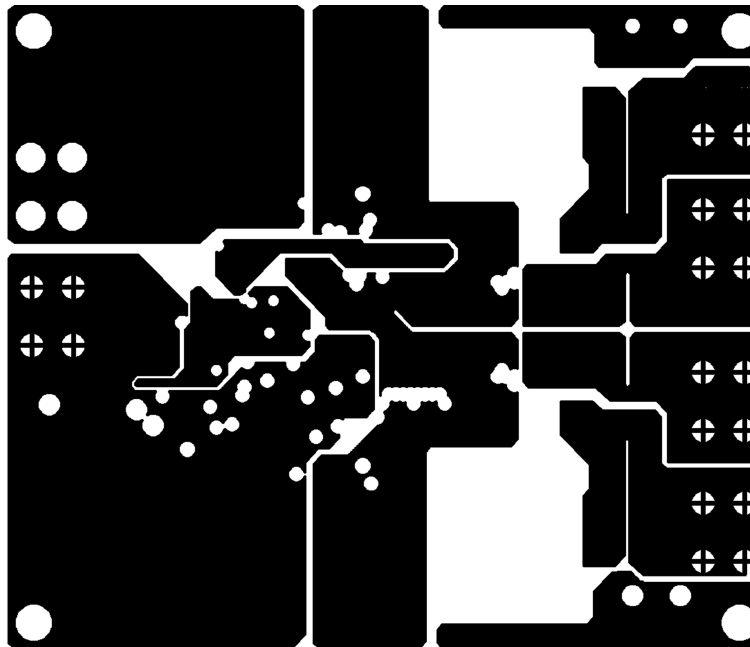
TOP SILKSCREEN (.PLC) AS VIEWED FROM TOP



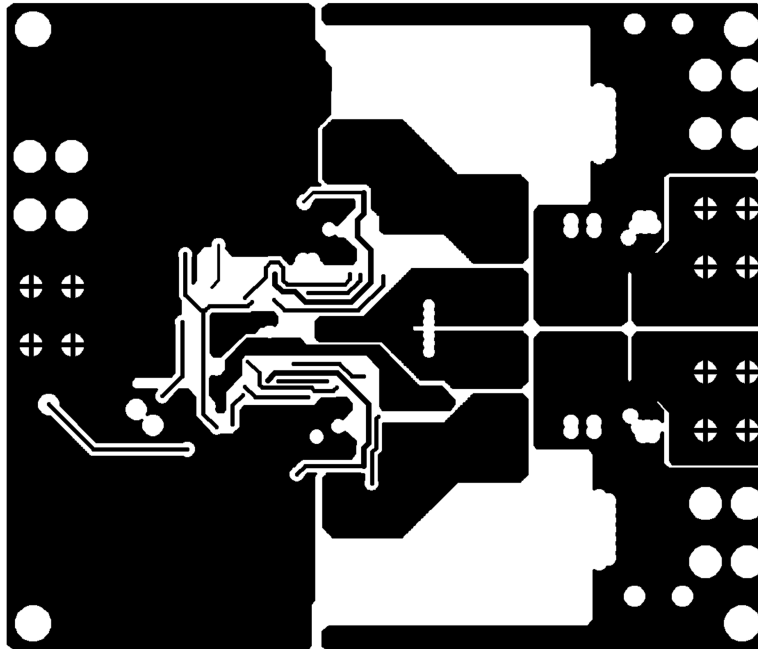
BOTTOM SILKSCREEN (.PLS) AS VIEWED FROM TOP



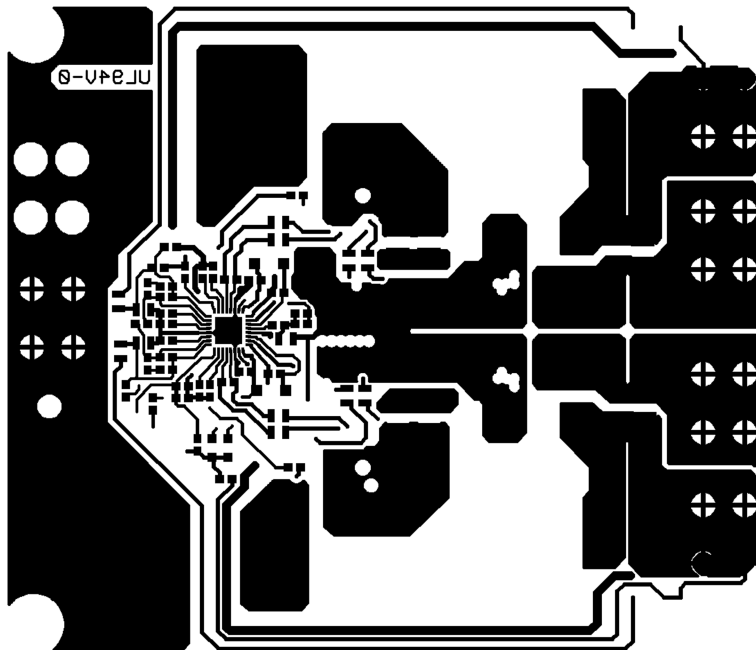
TOP COMPONENT LAYER (CMP) AS VIEWED FROM TOP



LAYER 2 (LY2) AS VIEWED FROM TOP



LAYER 3 (.LY3) AS VIEWED FROM TOP



BOTTOM SOLDER LAYER (.SOL) AS VIEWED FROM TOP

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 DEGRADATION 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/lstds/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 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lstds/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, INDEMNITY 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
Copyright © 2023, Texas Instruments Incorporated

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