AN-1819 LM5118 Evaluation Board

User's Guide

Literature Number: SNVA334
April 2008

Contents

List of Figures

List of Tables

AN-1819 LM5118 Evaluation Board

The LM5118 evaluation board is designed to provide the design engineer with a fully functional, Emulated Current Mode Control, buck-boost power converter to evaluate the LM5118 controller IC. The evaluation board provides a 12V output with 3A of output current capability. The evaluation board's wide input voltage range is from 75V to 5V, with operation down to 3V with some component changes. The evaluation board operates at 300 kHz, a good compromise between conversion efficiency, tradeoffs between buck and buck-boost mode requirements, and converter size. The printed circuit board consists of 4 layers with 2 ounce copper top and bottom, and 1 ounce copper on internal layers. The board is constructed with FR4 material. This application note contains the evaluation board schematic, Bill-of-Materials (BOM) and a quick setup procedure. Refer to the LM5118 data sheet and quick start for more complete circuit and design information.

1 Introduction

The LM5118 evaluation board is designed to provide the design engineer with a fully functional, Emulated Current Mode Control, buck-boost power converter to evaluate the LM5118 controller IC. The evaluation board provides a 12V output with 3A of output current capability. The evaluation board's wide input voltage range is from 75V to 5V, with operation down to 3V with some component changes. The evaluation board operates at 300 kHz, a good compromise between conversion efficiency, tradeoffs between buck and buck-boost mode requirements, and converter size. The printed circuit board consists of 4 layers with 2 ounce copper top and bottom, and 1 ounce copper on internal layers. The board is constructed with FR4 material. This application note contains the evaluation board schematic, Bill-of-Materials (BOM) and a quick setup procedure. Refer to the LM5118 data sheet and quick start for more complete circuit and design information.

2 IC Features

- Integrated high and low side driver
- Internal high voltage bias regulator
- Ultra-wide input voltage range: 5V to 75V
- Emulated current mode control
- Single inductor architecture
- VOUT operation below and above VIN
- Single resistor sets oscillator frequency
- Oscillator synchronization capability
- Programmable soft-start
- Ultra low (<10 μA) shutdown current
- Enable input
- Wide bandwidth error amplifier
- Adjustable output voltage 1.23V-75V
- 1.5% feedback reference accuracy
- Thermal Shutdown
- No VIN to VOUT connection during fault protection

3 Package

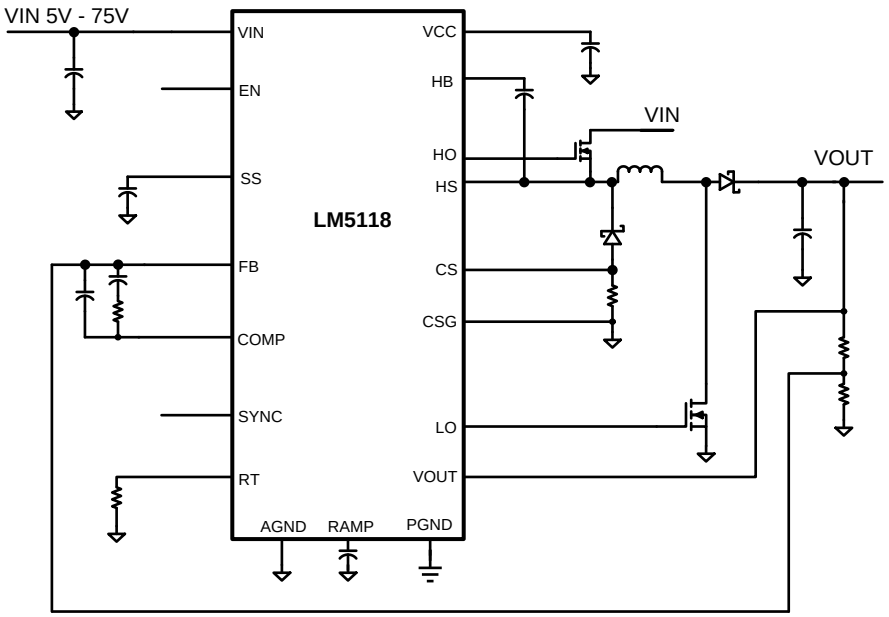


Figure 1. TSSOP-20EP (Exposed Pad)

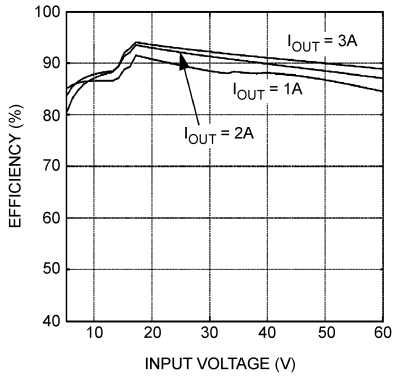


Figure 2. Efficiency

Figure 2 illustrates the efficiency of the converter vs. input voltage and output current. These curves highlight the high efficiency of the converter, especially considering the simplicity of design offered by a non synchronous implementation. Note the discontinuity in the curves at approximately 17V and 13V which represent mode transition boundaries. The lower efficiencies in the buck-boost region reflect additional losses at higher input and inductor currents. The decrease in efficiency at higher input voltages represents higher switching losses.

The performance of the evaluation board is as follows:

Input Range: 75V to less than 5V at full current

Operation to 3V at reduced current and appropriate adjustments*

Output Voltage: 12V

Output Current: 0 to 3A

Frequency of Operation: 300 kHz

Board Size: 3.45 X 2.65 inches

Load Regulation: 1%

Line Regulation: .1%

Over-Current Limiting

Operation with VIN greater or less than Vout

*Operation at full current to around 3V is possible with current limit sense resistor, UVLO threshold, and corresponding C_{ramp} adjustment. Additional input capacitance may be required. See the datasheet and quick start for more details.

4 Air Flow

Prolonged operation without airflow at low input voltage and at at full power will cause the MOSFET's and Diodes to overheat. A fan with a minimum of 200 LFM should always be provided. Figure 3 illustrates the temperature rise of various components with no airflow. The ambient was 25°C, and VIN was 8V.

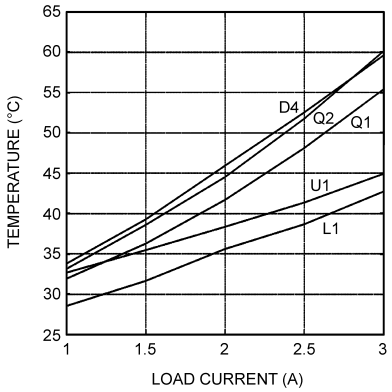


Figure 3. Temperature vs Load Current with No Airflow – 25°C Ambient

5 Powering Up

Connecting the IC's enable pin to ground will allow powering up the source supply with a minimal output load. Set the current limit of the source supply to provide about 1.5 times the anticipated wattage of the load. Note that input currents become very high at low input voltages, which requires an appropriate input supply. As you remove the connection from the enable pin to ground, immediately check for 12 volts at the output.

A quick efficiency check is the best way to confirm that everything is operating properly. If something is amiss, you can be reasonable sure that it will affect the efficiency adversely. Few parameters can be incorrect in a switching power supply without creating losses and potentially damaging heat.

6 Over Current Protection

The evaluation board is configured with over-current protection. The output current is limited to approximately 4.5 amps in the buck-boost mode The 4.5A value allows for component tolerances to guarantee a 3A output current. Note this current will be almost double, or about 7 amps in buck mode (Vin greater than 17 volts) due to the difference in peak inductor currents in the two different modes. However, a hard short will trigger the hiccup mode of current limit as illustrated in Figure 4. In this mode, the average output current will be less than .2 amps.

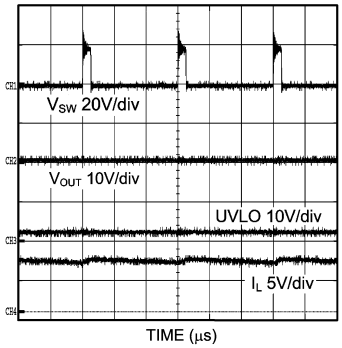


Figure 4. Short Circuit Current

7 VCCX

A place for a jumper between VOUT and VCCX is provided on the PC board. If operation below about 6 volts is required, connect the jumper to allow VCCX to power the converter (the exact voltage depends on the gate drive requirements of the switching FETs). The converter does require a minimum VIN of 5V to initially start. When running, the input voltage can decrease to below 5V at reduced current with VCCX connected to VOUT. Note that this design uses a current limit value to guarantee a full 3A of output current at a minimum VIN of 5V. For operation lower than 5V, the current limit resistor, UVLO threshold, and ramp capacitor must be re-calculated. Caution: make sure the input supply can source the required input current. Operation at low VIN at full power may overheat and damage the MOSFET's and Diodes supplied on the board. Note there is a limit of 14 volts applied to VCCX. Never exceed this value if operating VCCX from an external source, or operating the board with Vout greater than 12 volts. To prevent oscillation, connect and additional 100uF or greater electrolytic capacitor across Vin for input voltages less than 5 volts.

8 Mode Transition

With Vout set at 12 volts, the LM5118 applications board will operate in the buck mode with VIN greater than about17 volts. As VIN is reduced below 17 volts, the converter begins to operate in a soft buck-boost mode. As VIN is decreased below 14 volts, the converter smoothly transitions to a pure buck-boost mode. This method of mode transition insures a smooth, glitch free operation as VIN is varied over the transition region.

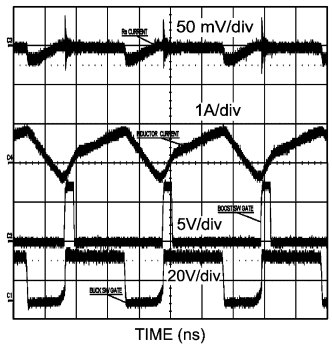
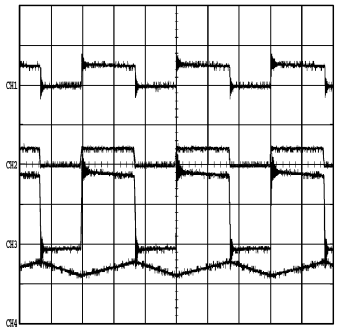


Figure 5. Mode Transition

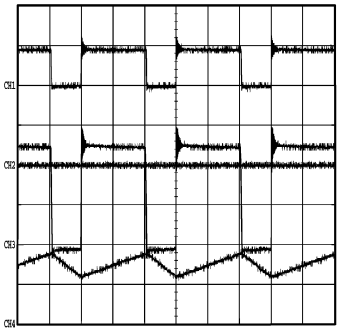
Figure 5 illustrates soft mode transition. The boost switch pulse-width is relatively narrow compared to the buck switch waveform. The boost switch pulse-width will gradually increase as VIN decreases, and will eventually match and lock to the buck switch waveform. At this point, the converter enters full buck-boost operation.

9 Typical Waveforms



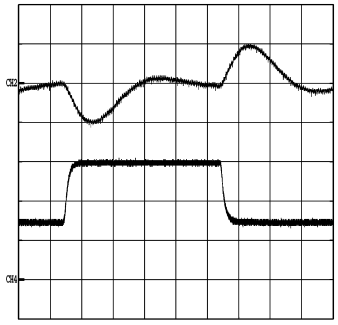
CH1: V_{SW} = 20V/div
CH2: Q1 = 20V/div
CH3: Q2 = 10V/div
CH4: I_L = 5A/div

Figure 6. Vin = 10V, Iout = 1A, illustrating Buck-Boost Operation



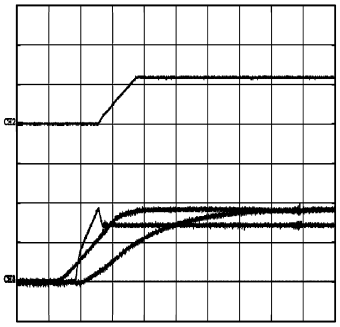
CH1: V_{SW} = 20V/div
CH2: Q1 = 20V/div
CH3: Q2 = 10V/div
CH4: I_L = 2A/div

Figure 7. Vin = 18V, Iout = 3A Illustrating Buck Operation



CH2: V_{OUT} = 0.1V/div
CH4: I_{OUT} = 1A/div

Figure 8. Transient Response



CH1: V_{IN} = 10V/div
CH2: V_{OUT} = 10V/div
CH3: VCC = 5V/div
CH4: UVLO = 5V/div

Figure 9. Start-Up Waveforms

10 Evaluation Board

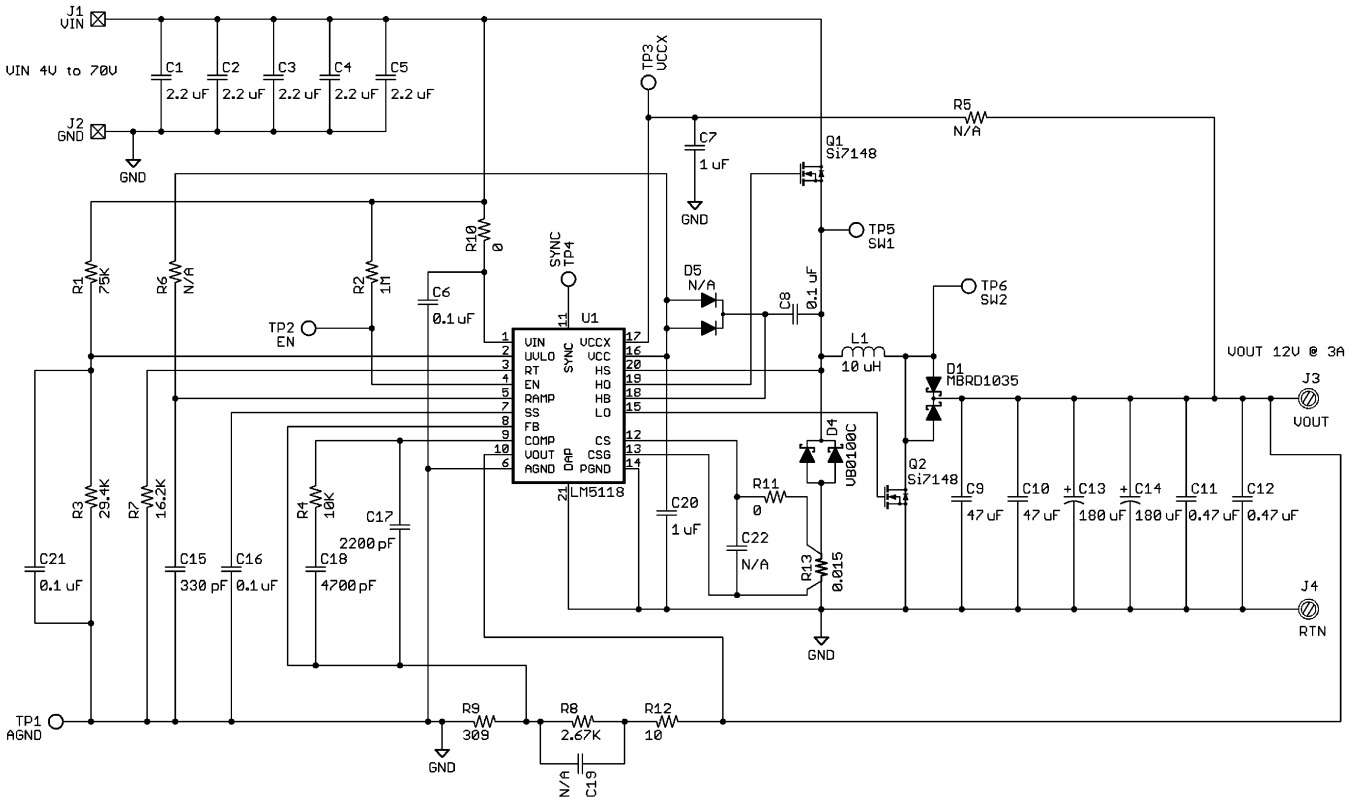


Figure 10. Evaluation Board Schematic

Table 1. Bill of Materials

Qty	Reference	Value	Device	Part Number	Manufacturer
2	C1, C2	2.2 µF, 100V, X7R	SMD 1812	C4532X7R2A225KT	
3	C3, C4, C5	2.2 µF, 100V, X7R	SMD 1812	C4532X7R2A225KT	TDK
2	C6, C8	0.1 µF, 100V, X7R	SMD 0805	GCM21BR72A104KA37L	MURATA
2	C7, C20	1 µf, 25V, X7R	SMD 0805	GCM21BR71E105KA56L	MURATA
2	C9, C10	47 µF, 16V, X5R	SMD 1210	ECJ-4YB1C476M	PANASONIC
2	C11, C12	0.47 µF, 25V, X7R	SMD 0805	GRM21BR71E474KC01L	MURATA
2	C13, C14	180 µF, 16V	CAP, ELECTR POLY, SMD	PXA160ARA181MJ80G	NIPPON CHEMICON
1	C15	330 pF, 100V, COG	CAP_SMDC0603	GRM1885C2A331JA01D	MURATA
1	C16	0.1 µF, 100V, X7R	CAP_SMDC0603	GCM188R72A104KA37D	MURATA
1	C17	2200 pf, 100V, COG	CAP_SMDC0603	GRM1885C1H222JA01D	MURATA
1	C18	4700 pF	CAP_SMDC0603	C1608X7R2A472M	TDK
2	C19, C22	N/A	CAP_SMDC0603		
1	C21	0.1 µF	CAP_SMDC0603	GRM188R72A104KA35D	MURATA
1	D1	SCHOTTKY 10A 35V	DPAK TO-252	MBRD1035CTLT4G	ON-SEMI
1	D4	SCHOTTKY 40A 100V	D2PAK TO-263AB	VB40100C-E3/4W	VISHAY
1	D5	N/A	SOT-23		
1	J1, J2	INPUT	TERMINAL_TURRET	1503-2	KEYSTONE
1	J3, J4	OUTPUT	TERMINAL15A	7693	KEYSTONE
1	L1	10 µH	IND_SER2800	SER2814H-103	COILCRAFT
1	L1A	N/A			
2	Q1, Q2	NFET	PPAK_SO8	SI7148DP-T1-E3	VISHAY
1	R1	75.0K, 1%	SMD 0603	ERJ-3EKF7502V	PANASONIC
1	R2	1M, 1%	SMD 0603	ERJ-S03F1004V	PANASONIC
1	R3	29.4K, 1%	SMD 0603	ERJ-3EKF2942V	PANASONIC
1	R4	10K, 1%	SMD 0603	ERJ-3EKF1002V	PANASONIC
1	R5	N/A	SMD 0603		
1	R6	OMIT			
1	R7	16.2K, 1%	SMD 0603	ERJ-3EKF1622V	PANASONIC
1	R8	2.67K, 1%	SMD 0603	ERJ-3EKF2671V	PANASONIC
1	R9	309, 1%	SMD 0603	ERJ-3EKF3090V	PANASONIC
1	R10	0Ω, 1%	SMD 1206	ERJ-8GEY0R00V	PANASONIC
1	R11	0Ω, 1%	SMD 0603	ERJ-3GEY0R00V	PANASONIC
1	R12	10Ω, 1%	SMD 0603	ERJ-3EKF10R0V	PANASONIC
1	R13	0.015Ω, 2W, 2%	SMD 7520	RL7520WT-R015-F	SUSUMU
1	TP1, TP2, TP3, TP4, TP5, TP6	TEST	TEST_POINT2	5012	KEYSTONE
1	U1	IC, PWM	TSSOP 20	LM5118MH	NATIONAL SEMICONDUCTOR

11 Schematic and Layout

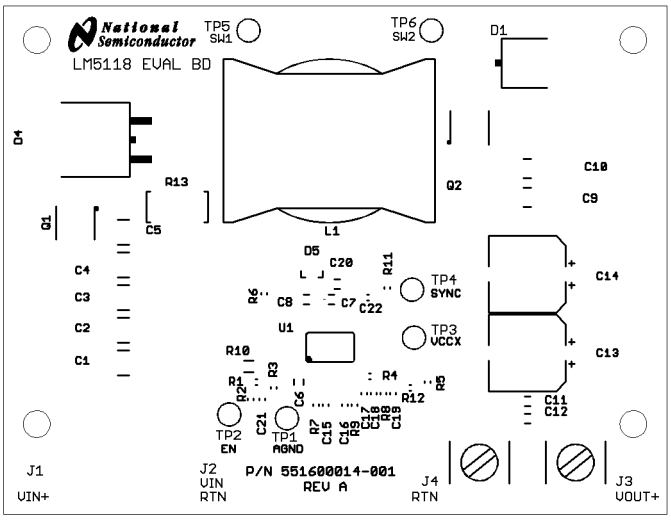


Figure 11. Top Silkscreen Layer as Viewed from Top

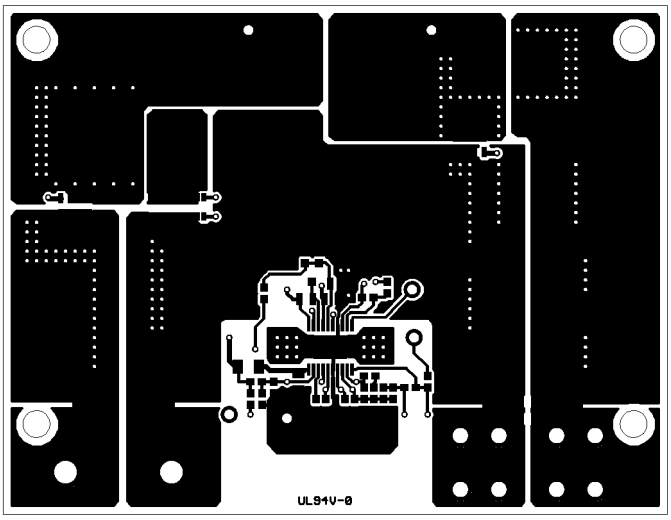


Figure 12. Top Layer as Viewed from Top

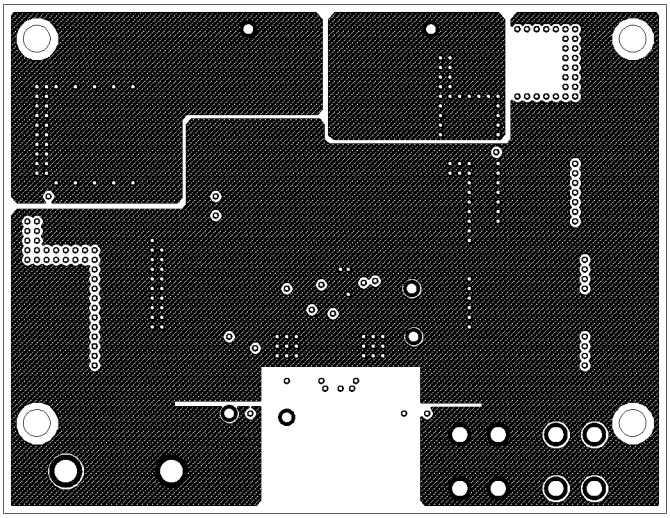


Figure 13. Layer 2 as Viewed from Top

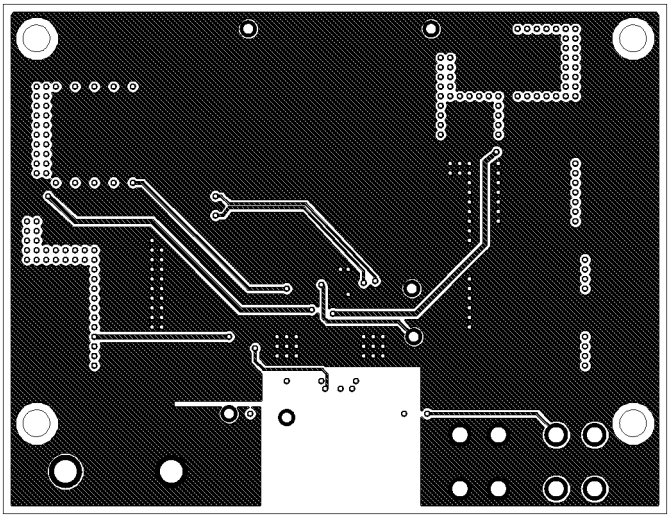


Figure 14. Layer 3 as Viewed from Top

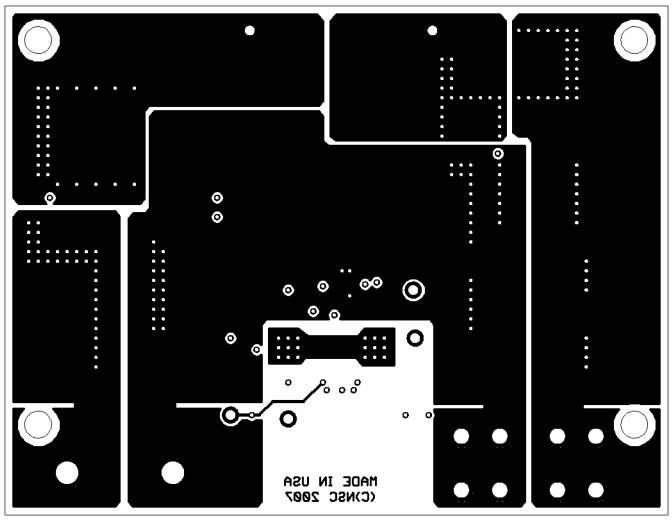


Figure 15. Bottom Layer as Viewed from Top

Figure 16. Bottom Silkscreen Layer as Viewed from Top

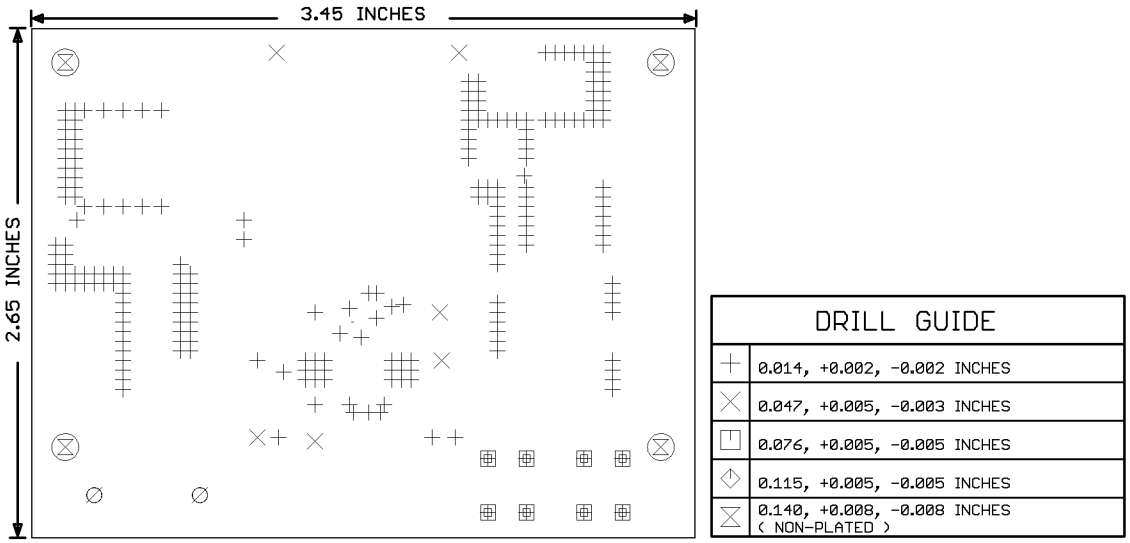


Figure 17. Drills and Dimensions as Viewed from Top

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.

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. 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.

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.

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

http://www.tij.co.jp

【ご使用にあたっての注】

本開発キットは技術基準適合証明を受けておりません。

本製品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
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.

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

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

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 as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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