AN-2066 LM25119 Evaluation Board

1 Introduction

The LM25119EVAL evaluation board provides the design engineer with a fully functional dual output buck converter, employing the LM25119 Dual Emulated Current Mode Synchronous Buck Controller. The evaluation board is designed to provide both 3.3V and 1.8V outputs over an input range of 6.0V to 36V. Also the evaluation board can be easily configured for a single 3.3V, 16A regulator.

2 Performance of the Evaluation Board

- Input Voltage Range: 6.0V to 36V
- Output Voltage: 3.3V (CH1), 1.8V (CH2)
- Output Current: 8A (CH1), 8A (CH2)
- Nominal Switching Frequency: 230 KHz
- Synchronous Buck Operation: Yes
- Diode Emulation Mode: Yes
- Hiccup Mode Overload Protection: Yes
- External VCC Sourcing: No

3 Powering and Loading Consideration

When applying power to the LM25119 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 0.5V. In this board design, UVLO setting is conservative while UVLO hysteresis setting is aggressive. Minimum input voltage can goes 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 LM25119. For complete design information, see the *LM25119/LM25119Q Wide Input Range Dual Synchronous Buck Controller Data Sheet* (SNVS680).

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.

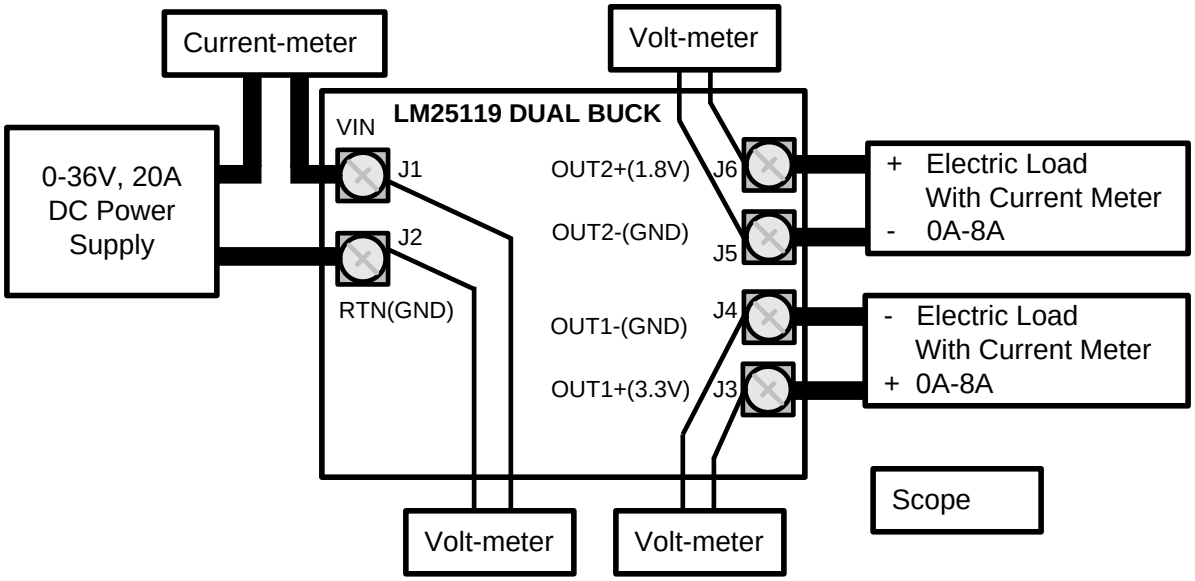


Figure 1. Typical Evaluation Setup

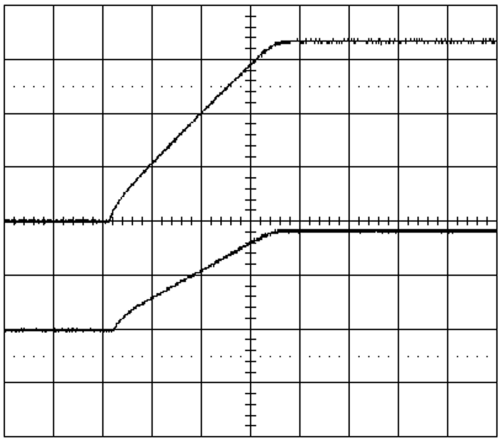
3.5 Quick Start-Up Procedure

1. Set the power supply current limit to at least 20A. Connect the power supply to J1 and J2.
2. Connect one load with an 8A capacity between J3 and J4. Connect another load with an 8A capacity between J6 and J5.
3. Set input voltage to 12V and turn it on.
4. Measure the output voltages. CH1 should regulate at 3.3V and CH2 should regulate at 1.8V.
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 6.0V to 36V while monitoring the output voltages. The outputs should remain in regulation.

4 Waveforms

4.1 Soft Start

When applying power to the LM25119 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 0.5Ω on the 3.3V output, and 0.33Ω on the 1.8V output, respectively.

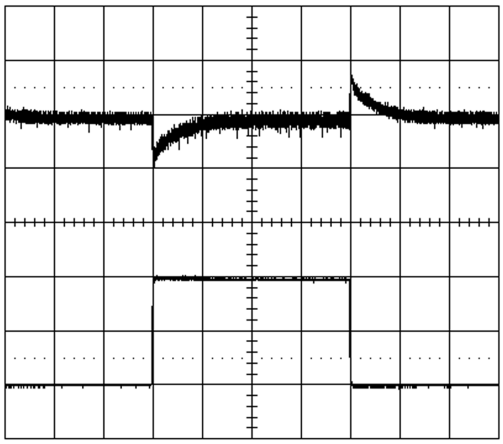


Conditions:
Input Voltage = 12VDC
0.5Ω Load on 3.3V output
0.33Ω Load on 1.8V output
Traces:
Top Trace: 3.3V Output Voltage, Volt/div = 1V
Bottom Trace: 1.8V Output Voltage, Volt/div = 1V
Horizontal Resolution = 1 ms/div

Figure 2. Start-up with Resistive Load

4.2 Load Transient

Figure 3 shows the transient response for a load of change from 2A to 6A on 3.3V output. The upper waveform shows output voltage droop and overshoot during the sudden change in output current shown by the lower waveform.

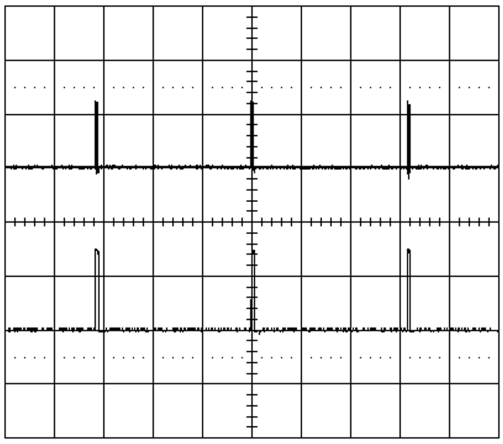


Conditions:
Input Voltage = 12VDC
Output Current 2A to 6A
Traces:
Top Trace: 3.3V Output Voltage, Volt/div = 100mV, AC coupled
Bottom Trace: Output Current Amp/Div = 2A
Horizontal Resolution = 0.5 ms/div

Figure 3. Load Transient Response

4.3 Over Load 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 CH1 output. One channel may operate in the normal mode while the other is in hiccup mode overload protection.

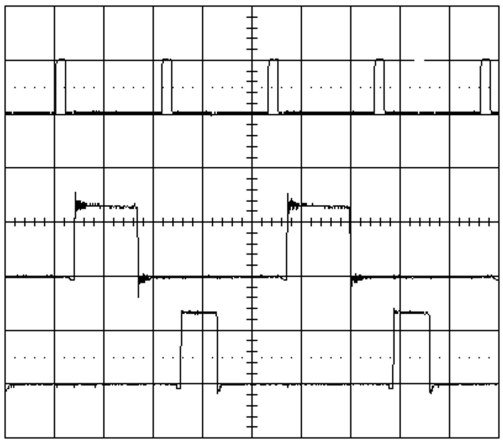


Conditions:
Input Voltage = 12VDC
Output Short on 3.3V
Traces:
Top Trace: SW voltage on CH1, Volt/div = 10V
Bottom Trace: Inductor Current Amp/div = 10A
Horizontal Resolution = 20 ms/div

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.

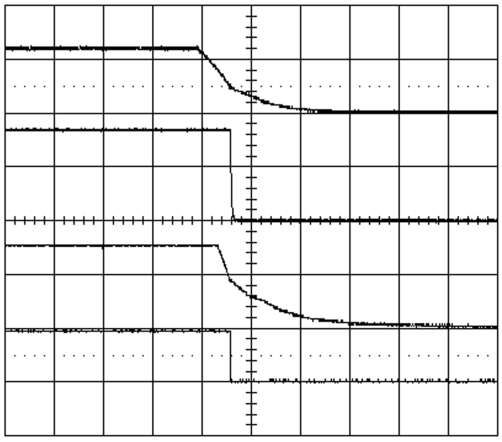


Conditions:
Input Voltage = 12VDC
8A on 3.3V output
8A on 1.8V output
Traces:
Top Trace: SYNC pulse, Volt/div = 5V
Middle Trace: SW voltage on CH1, Volt/div = 10V
Bottom Trace: SW voltage on CH2, Volt/div = 10V
Horizontal Resolution = 1 µs/div

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 = 12VDC
0.5Ω Load on 3.3v output
Traces:
Top Trace: Input Voltage, Volt/div = 10V
Middle Trace1: 3.3V 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 90% at 12V 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.

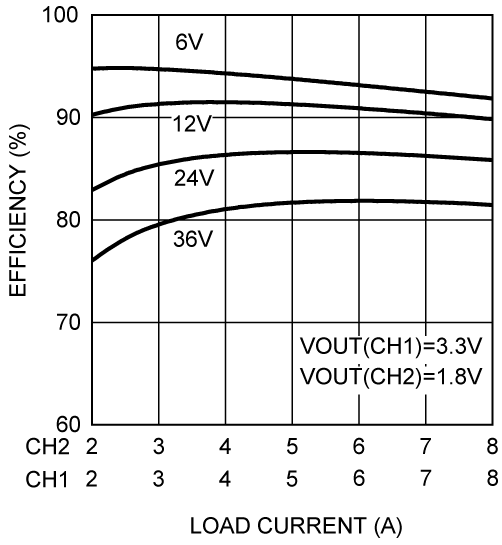


Figure 7. Typical Efficiency vs Load Current

6 Board Configuration

6.1 Interleaved Buck Operation for Single 3.3V 16A Output

The evaluation board is designed to be easily converted to a 3.3V, 16A 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 3.3V output with 16A maximum output current, populate R21 and R22 with 0Ω resistor and open R6, C15 and C14. The electronic load should have over 16A capability to test the interleaved operation.

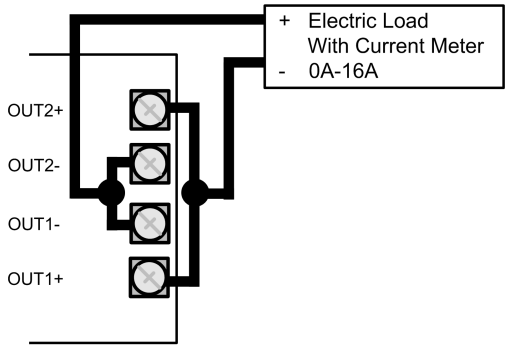


Figure 8. Load Connection for Single Output

6.2 External VCC Supply and VCC Disable

External VCC supply helps to reduce the temperature and the power loss of the LM25119 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.

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).

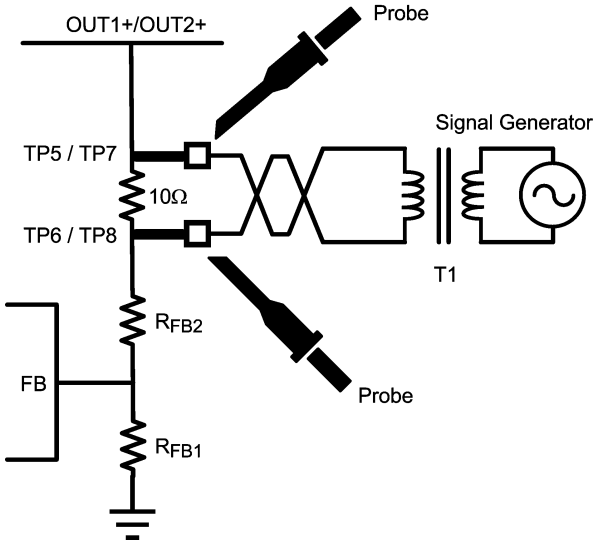


Figure 9. Loop Response Measurement Setup

7 Evaluation Board Schematic

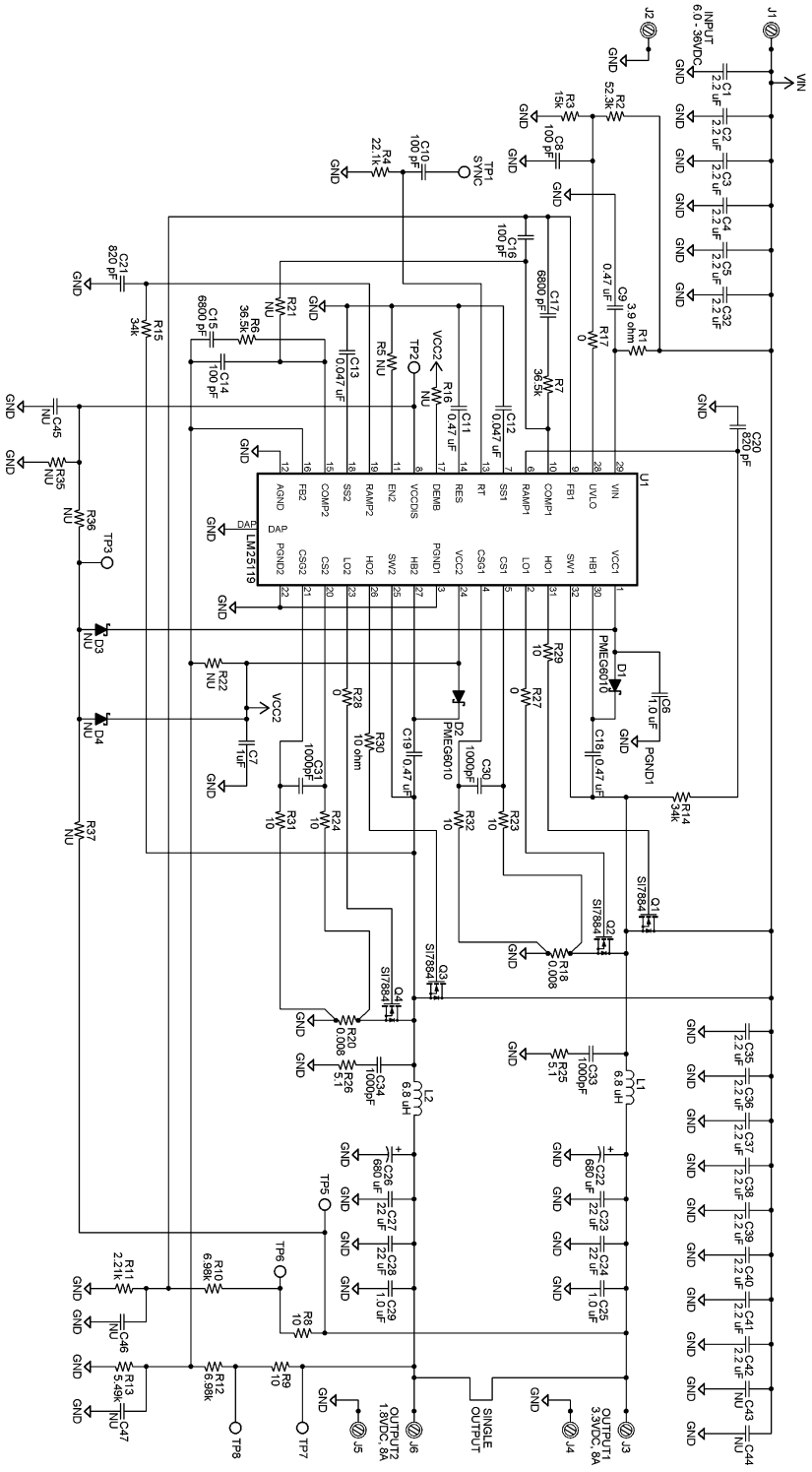
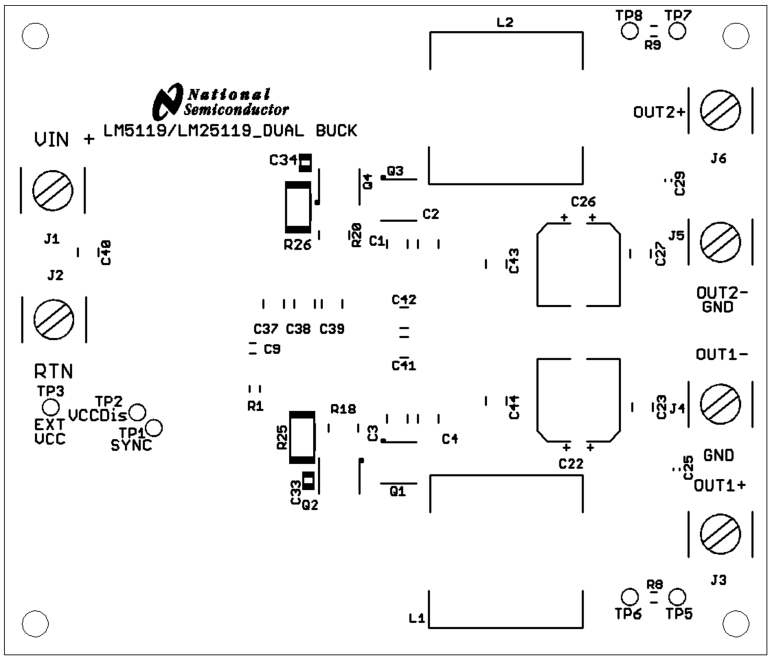


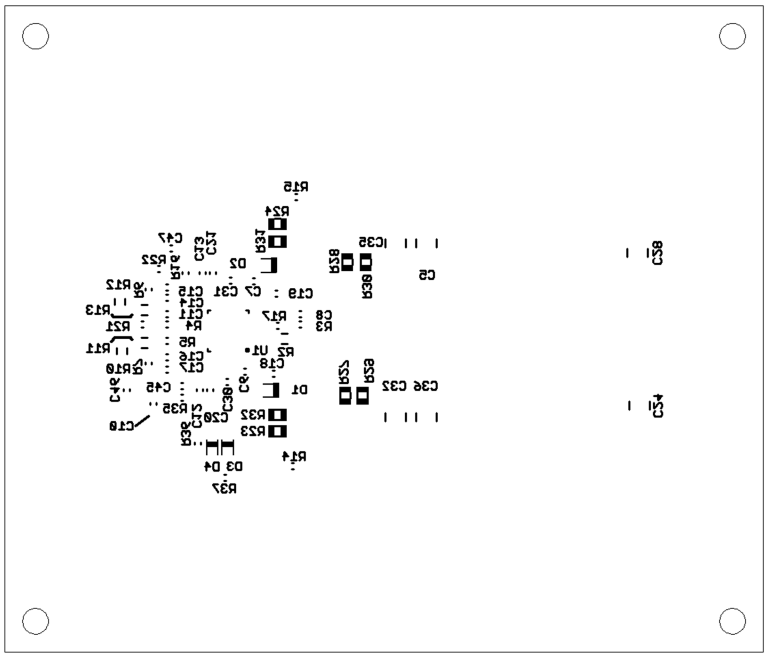
Table 1. Bill of Materials (BOM)

Part	Value	Package	Part Number	Manufacturer
C1,C2,C3,C4,C5,C32,C35,C36,C37,C38,C39,C40,C41,C42	2.2 µF, 50V, X7R	1210	C3225X7R1H225K	TDK
C6,C7,C25,C29	1µF, 16V, X7R	0603	C1608X7R1C105K	TDK
C8,C10,C14,C16	100pF, 50V, C0G	0603	C1608C0G1H101J	TDK
C9	0.47µF, 50V, X7R	0805	UMK212B7474KG	Taiyo Yuden
C11,C18,C19	0.47µF, 25V, X7R	0603	GRM188R71E474KA12	Murata
C12,C13	0.047µF, 16V, X7R	0603	C1608X7R1C473K	TDK
C15,C17	6800pF, 25V, C0G	0603	C1608C0G1E682J	TDK
C20,C21	820pF, 50V, C0G	0603	C1608C0G1H821J	TDK
C22,C26	680µF, 6.3V	Φ10	APXA6R3ARA681MJC0G	NIPPON CHEMI-CON
C23,C24,C27,C28	22µF,10V, X7R	1210	C1210C226K8RAC	Kemet
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	52.3k, 1%	0805	MCR10EZHF5232	Rohm
R3	15k, 1%	0603	MCR03EZPFX1502	Rohm
R4	22.1k, 1%	0603	CRCW060322K1FKEA	Vishay
R5,R16,R21,R22,R35,R36,R37	NU			
R6,R7	36.5k, 1%	0603	CRCW060336K5FKEA	Vishay
R8,R9, R23,R24,R29,R30, R31, R32	10 ohm, 5%	0805	CRCW080510R0JNEA	Vishay
R10,R12	6.98k, 1%	0805	CRCW08056K98FKEA	Vishay
R11	2.21k, 1%	0805	MCR10EZHF2211	Rohm
R13	5.49k, 1%	0805	MCR10EZHF5491	Rohm
R14,R15	34k, 1%	0603	CRCW060334K0FKEA	Vishay
R17	0 ohm	0603	MCR03EZPJ000	Rohm
R18,R20	0.008 ohm, 1W, 1%	0815	RL3720WT-R008-F	Susumu
R25,R26	5.1 ohm, 1W, 1%	2512	ERJ-1TRQF5R1U	Panasonic-ECG
R27,R28	0 ohm, 5%	0805	MCR10EZPJ000	Rohm
D1,D2	60V, 1A	SOD123F	PMEG6010CEH	NXP
D3,D4	NU			
L1,L2	6.8µH, 18.5A	18.2x18.3	7443556680	WE
Q1,Q2,Q3,Q4	40V, 58A	PowerPAK SO-8	SI7884BDP	Vishay
U1		WQFN32	LM25119	TI
J1,J2,J3,J4,J5,J6	15A		7693	Keystone
TP1,TP2,TP3		Φ10	5002	Keystone
TP5,TP6,TP7,TP8			1040	Keystone

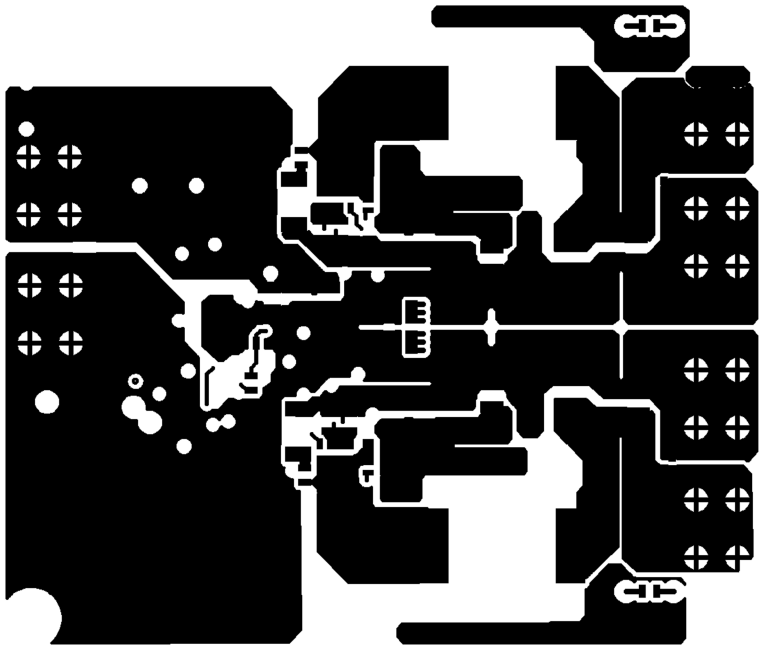
8 PCB Layout



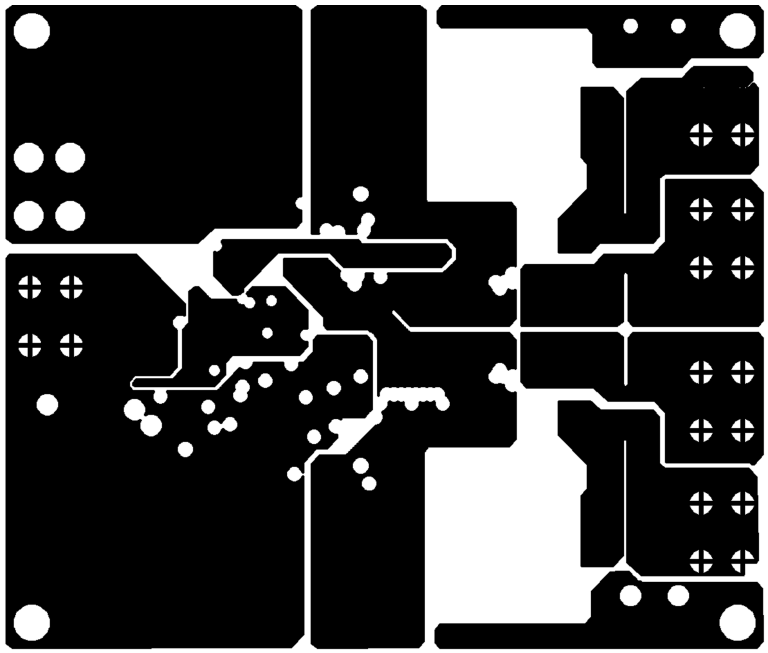
TOP SILKSCREEN (.PLC) AS VIEWED FROM TOP



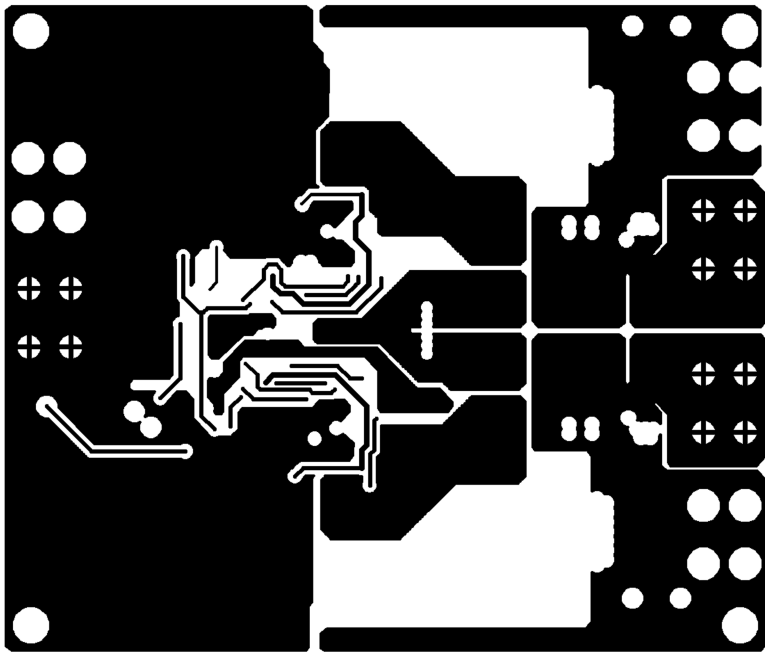
BOTTOM SILKSCREEN (.PLS) AS VIEWED FROM TOP



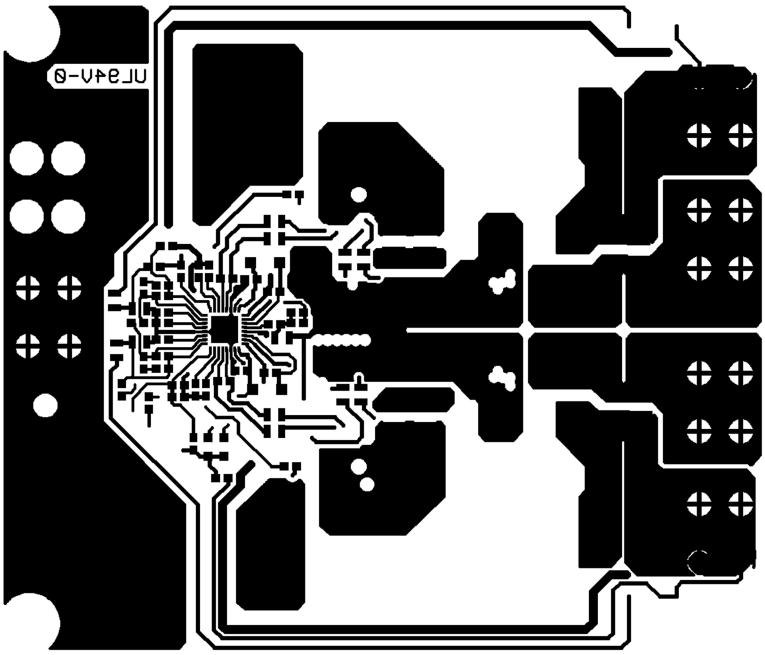
TOP COMPONENT LAYER (.CMP) AS VIEWED FROM TOP



LAYER 2 (.LY2) AS VIEWED FROM TOP



LAYER 3 (.LY3) AS VIEWED FROM TOP



BOTTOM SOLDER LAYER (.SOL) AS VIEWED FROM TOP

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WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

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

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

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

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西新宿三井ビル

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

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

3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

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