AN-1819 LM5118 Evaluation Board

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 12 V output with 3 A of output current capability. The evaluation board's wide input voltage range is from 75 V to 5 V, with operation down to 3 V 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 board is constructed with FR4 material. This user's guide contains the evaluation board schematic and Bill of Materials (BOM).

Refer to the LM5118 quick start (SNVU065) and for more complete circuit and design information, see *Wide Voltage Range Buck-Boost Controller* (SNVS566).

The performance of the evaluation board is:

- Input Range: 75 V to less than 5 V at full current
- Operation to 3 V at reduced current and appropriate adjustments. Operation at full current to around 3 V is possible with current limit sense resistor, UVLO threshold, and corresponding C_{ramp} adjustment. Additional input capacitance may be required. See the LM5118 datasheet (SNVS566) and quick start (SNVU065) for more details.
- Output Voltage: 12 V
- Output Current: 0 to 3 A
- Frequency of Operation: 300 kHz
- Board Size: 3.45 × 2.65 inches
- Load Regulation: 1%
- Line Regulation: 0.1%
- Over-Current Limiting
- Operation with V_{IN} greater or less than V_{OUT}

2 IC Features

- Integrated high and low side driver
- Internal high voltage bias regulator
- Ultra-wide input voltage range: 5 V to 75 V
- Emulated current mode control
- Single inductor architecture
- V_{OUT} operation below and above V_{IN}
- 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 1.23 V to 75 V

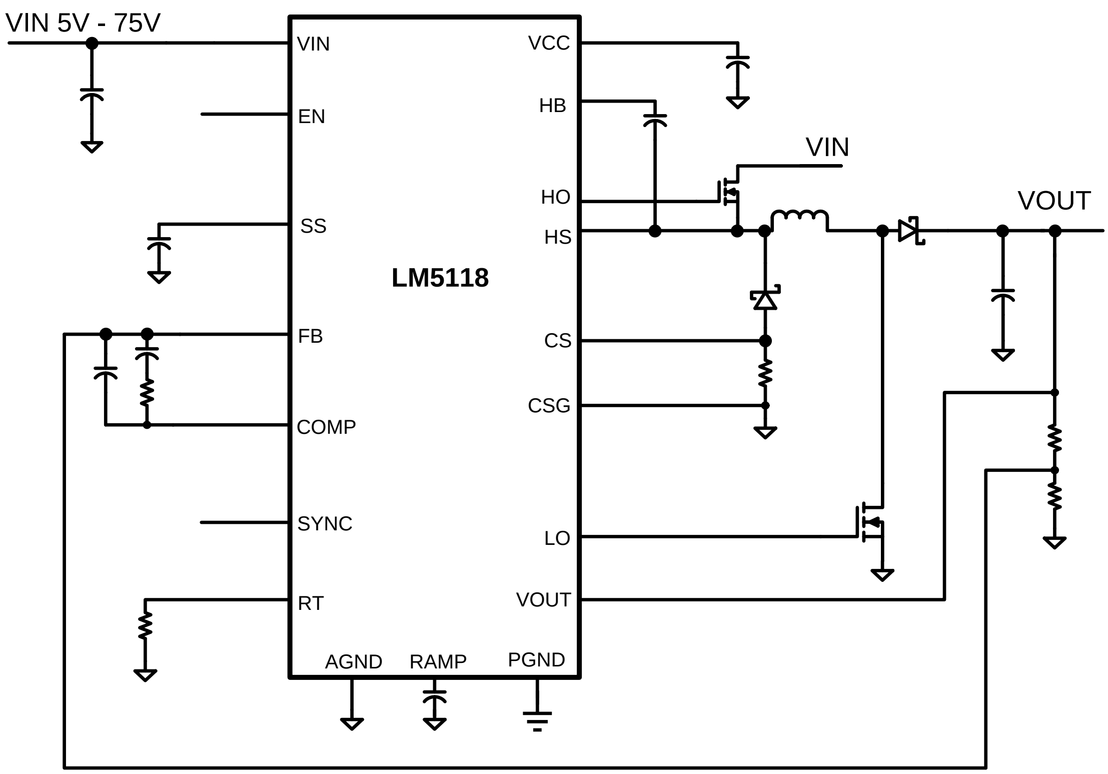
- 1.5% feedback reference accuracy
- Thermal Shutdown
- No V_{IN} to V_{OUT} connection during fault protection

3 Package

HTSSOP-20EP (Exposed Pad)

4 Application Circuit

See the detailed LM5118EVAL schematic at Figure 17



5 Efficiency

Figure 1 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 17 V and 13 V 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.

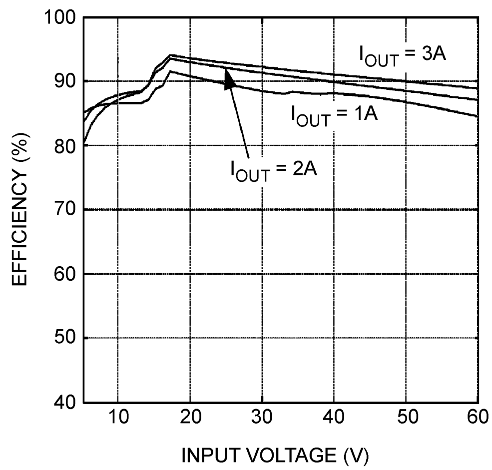


Figure 1. Efficiency

6 Air Flow

Prolonged operation without airflow at low input voltage and at full power will cause the MOSFETs and diodes to overheat. A fan with a minimum of 200 LFM should always be provided. Figure 2 illustrates the temperature rise of various components with no airflow. The ambient was 25°C, and V_{IN} was 8 V.

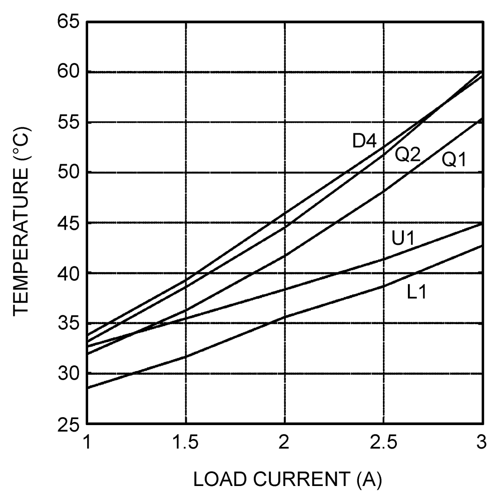


Figure 2. Temperature vs Load Current with No Airflow – 25°C Ambient

7 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 V 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.

8 Over Current Protection

The evaluation board is configured with over-current protection. The output current is limited to approximately 4.5 A in the buck-boost mode The 4.5 A value allows for component tolerances to guarantee a 3 A output current. Note this current will be almost double, or about 7 A in buck mode (VIN greater than 17 V) due to the difference in peak inductor currents in the two different modes.

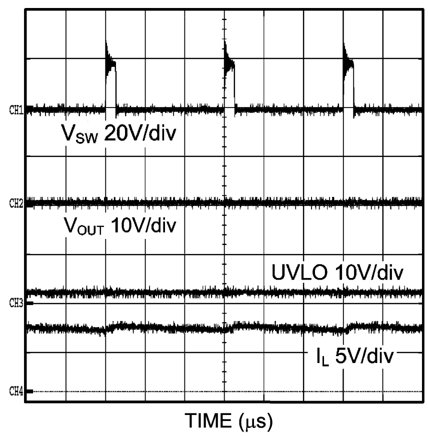


Figure 3. Short Circuit Current

9 VCCX

A place for a jumper between VOUT and VCCX is provided on the PC board. If operation below about 5 V 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 5 V to initially start. When running, the input voltage can decrease to below 5 V at reduced current with VCCX connected to VOUT. Note that this design uses a current limit value to guarantee a full 3 A of output current at a minimum V_{IN} of 5 V. For operation lower than 5 V, 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 V_{IN} at full power may overheat and damage the MOSFETs and diodes supplied on the board. Note there is a limit of 14 V applied to VCCX. Never exceed this value if operating VCCX from an external source, or operating the board with V_{OUT} greater than 12 V. To prevent oscillation, connect and additional 100 uF or greater electrolytic capacitor across V_{IN} for input voltages less than 5 V.

10 Mode Transition

With V_{OUT} set at 12 V, the LM5118 applications board will operate in the buck mode with VIN greater than about 17 V. As VIN is reduced below 17 V, the converter begins to operate in a soft buck-boost mode. As VIN is decreased below 14 V, 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 4 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.

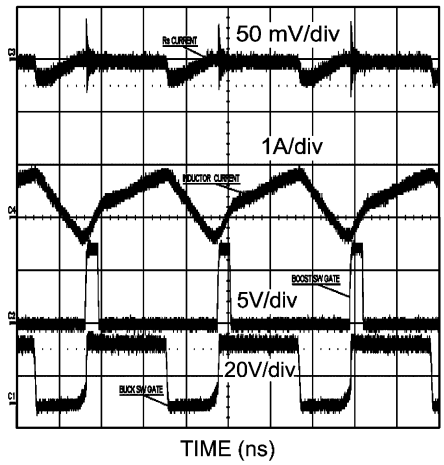


Figure 4. Mode Transition

11 Typical Waveforms

Note: All waveforms refer to revision B design.

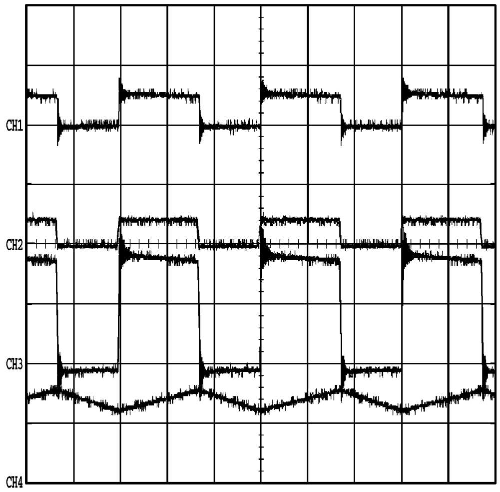


Figure 5. Illustrating Buck-Boost Operation
V_{IN} = 10 V, I_{OUT} = 1 A
CH1: V_{SW} = 20V/div; CH2: Q1 = 20V/div;
CH3: Q2 = 10V/div; CH4: I_L = 5A/div

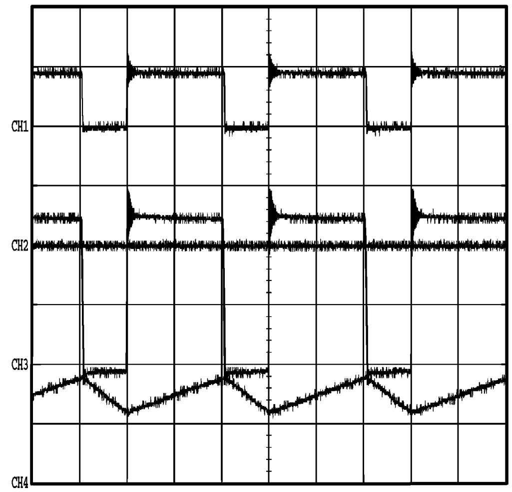


Figure 6. Illustrating Buck Operation
V_{IN} = 18 V; I_{OUT} = 3 A
CH1: V_{SW} = 20V/div; CH2: Q1 = 20V/div;
CH3: Q2 = 10V/div; CH4: I_L = 2A/div

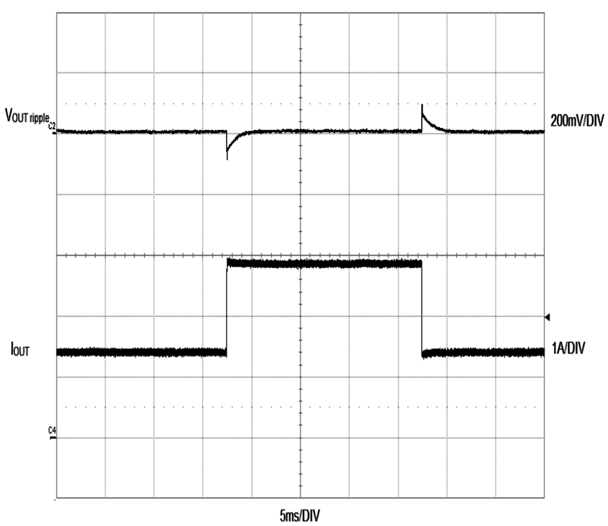


Figure 7. Buck Mode Transient Response
CH2: V_{OUT}ripple (ac coupled); CH4: I_{OUT} = I_{OUT}

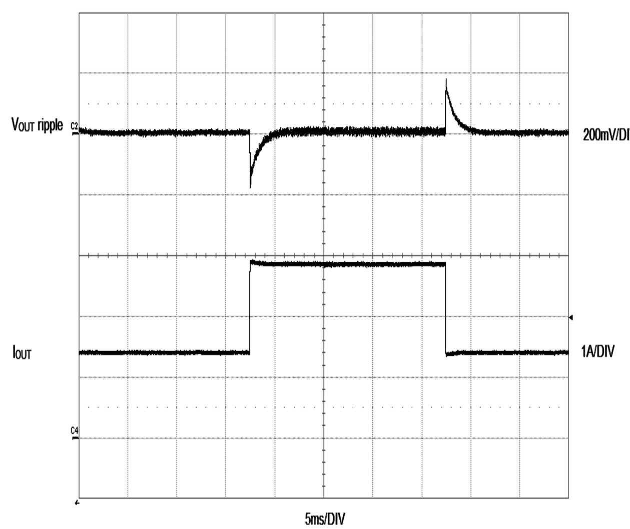


Figure 8. Buck-Boost Mode Transient Response
CH2 = V_{OUT} ripple (ac coupled); CH4 = I_{OUT}

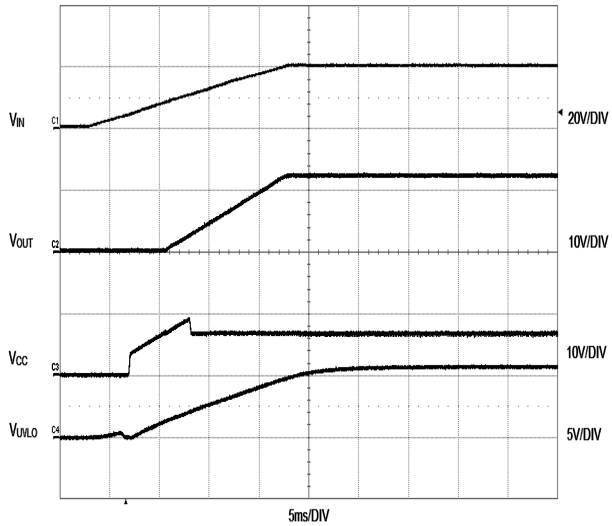


Figure 9. Start Up Waveforms
CH1 = V_{IN}; CH2 = V_{OUT};
CH3 = V_{CC}; CH4 = V_{UVLO}

12 Bill of Materials

Qty	Reference	Value	Device	Part Number	Manufacturer
5	C1, C2, C3, C4, C5	2.2uF, 100V, X7R	SMD 1812	C4532X7R2A225KT	TDK
2	C6, C8	0.1uF, 100V, X7R	SMD 0805	GCM21BR72A104KA37L	MURATA
2	C7, C20	1uf, 25V, X7R	SMD 0805	GCM21BR71E105KA56L	MURATA
2	C9, C10	47uF, 16V, X5R	SMD 1210	ECJ-4YB1C476M	PANASONIC
2	C11, C12	0.47uF, 25V, X7R	SMD 0805	GRM21BR71E474KC01L	MURATA
2	C13, C14	180uF, 16V	CAP, ELECTR POLY, SMD	PXA160ARA181MJ80G	NIPPON CHEMICON
1	C15	330pF, 100V, COG	CAP_SMDC0603	GRM1885C2A331JA01D	MURATA
1	C16	0.1uF, 100V, X7R	CAP_SMDC0603	GCM188R72A104KA37D	MURATA
1	C17	2200pf, 100V, COG	CAP_SMDC0603	GRM1885C1H222JA01D	MURATA
1	C18 (Rev A)	4700pF	CAP_SMDC0603	C1608X7R2A472M	TDK
1	C18 (Rev B)	0.1uF	CAP_SMDC0603	C1608X7S2A104K	TDK
0	C19, C22	DNP	CAP_SMDC0603		
1	C21	0.1uF	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
0	D5	DNP	SOT-23		
1	J1, J2	INPUT	TERMINAL_TURRET	1503-2	KEYSTONE
1	J3, J4	OUTPUT	TERMINAL15A	7693	KEYSTONE
1	L1	10uH	IND_SER2800	SER2814H-103	COILCRAFT
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
0	R5	DNP	SMD 0603		
0	R6	DNP			
1	R7 (Rev A)	16.2K, 1%	SMD 0603	ERJ-3EKF1622V	PANASONIC
1	R7 (Rev B)	18.2K, 1%	SMD 0603	ERJ-3EKF1822V	PANASONIC
1	R8	2.67K, 1%	SMD 0603	ERJ-3EKF2671V	PANASONIC
1	R9	309, 1%	SMD 0603	ERJ-3EKF3090V	PANASONIC
1	R10	0 OHM, 1%	SMD 1206	ERJ-8GEY0R00V	PANASONIC
1	R11	0 OHM, 1%	SMD 0603	ERJ-3GEY0R00V	PANASONIC
1	R12	10 OHM, 1%	SMD 0603	ERJ-3EKF10R0V	PANASONIC
1	R13	0.015 OHM, 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/NOPB	Texas Instruments

13 Layout

The printed circuit board consists of 4 layers with 2 ounce copper top and bottom, and 1 ounce copper on internal layers.

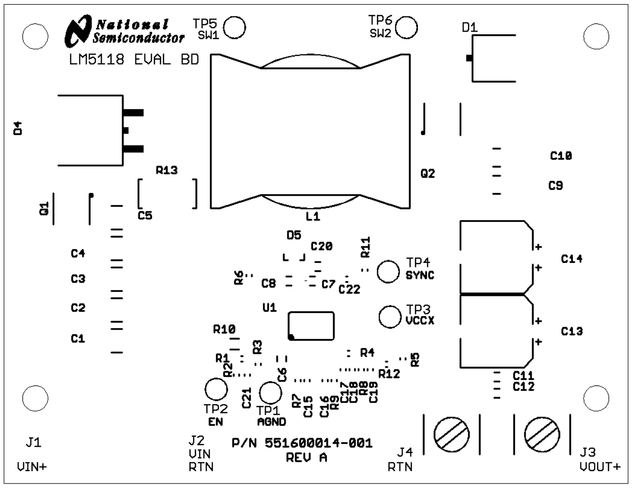


Figure 10. Top Silkscreen Layer as Viewed from Top

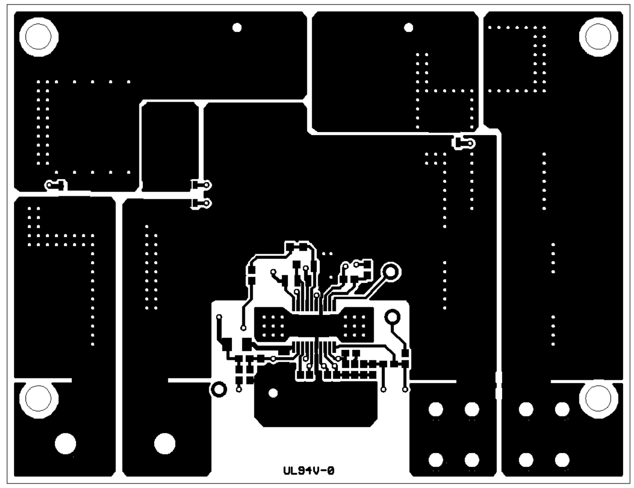


Figure 11. Top Layer as Viewed from Top

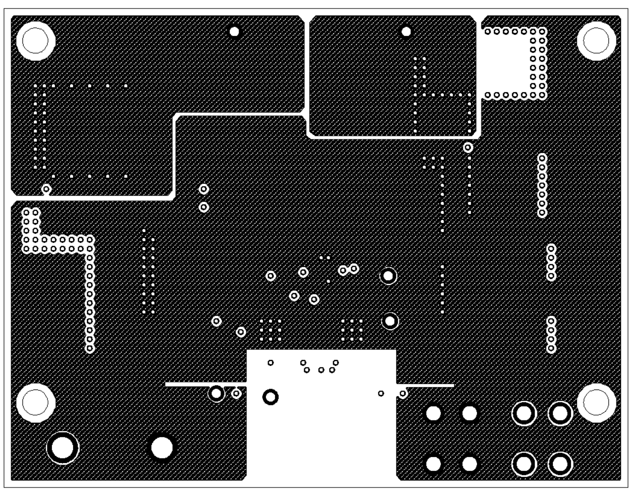


Figure 12. Layer 2 as Viewed from Top

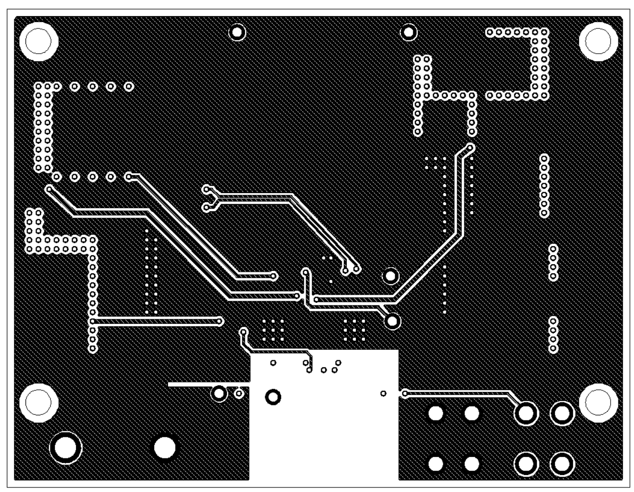


Figure 13. Layer 3 as Viewed from Top

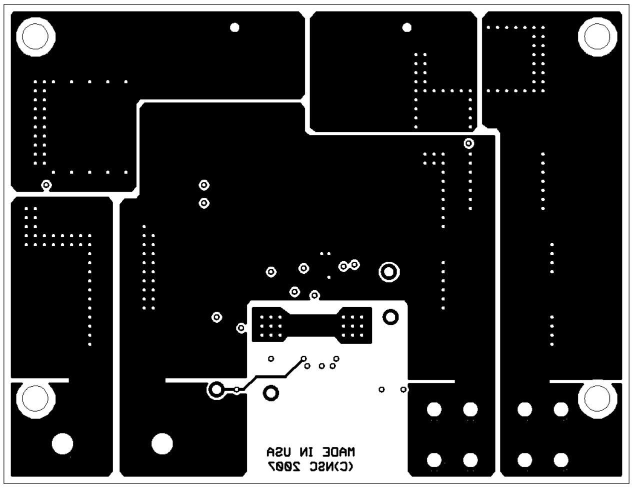
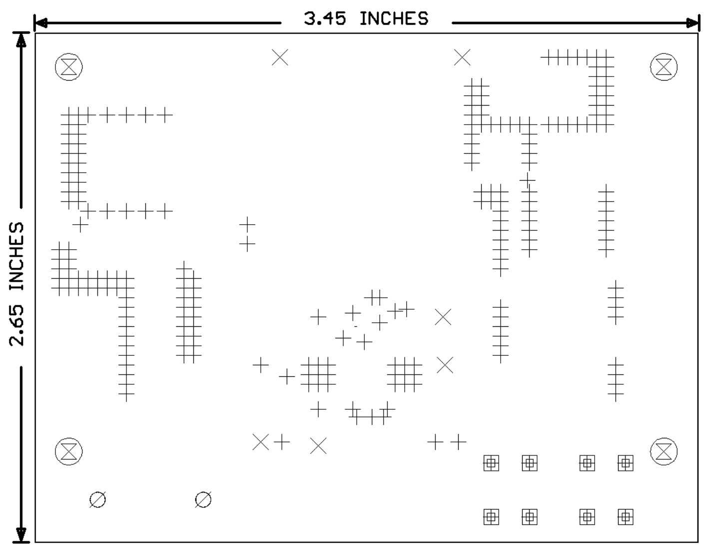


Figure 14. Bottom Layer as Viewed from Top

Figure 15. Bottom Silkscreen Layer as Viewed from Top



DRILL GUIDE	
+	0.014, +0.002, -0.002 INCHES
×	0.047, +0.005, -0.003 INCHES
□	0.076, +0.005, -0.005 INCHES
◇	0.115, +0.005, -0.005 INCHES
⧖	0.140, +0.008, -0.008 INCHES (NON-PLATED)

Figure 16. Drills and Dimensions as Viewed from Top

14 Evaluation Board Schematic

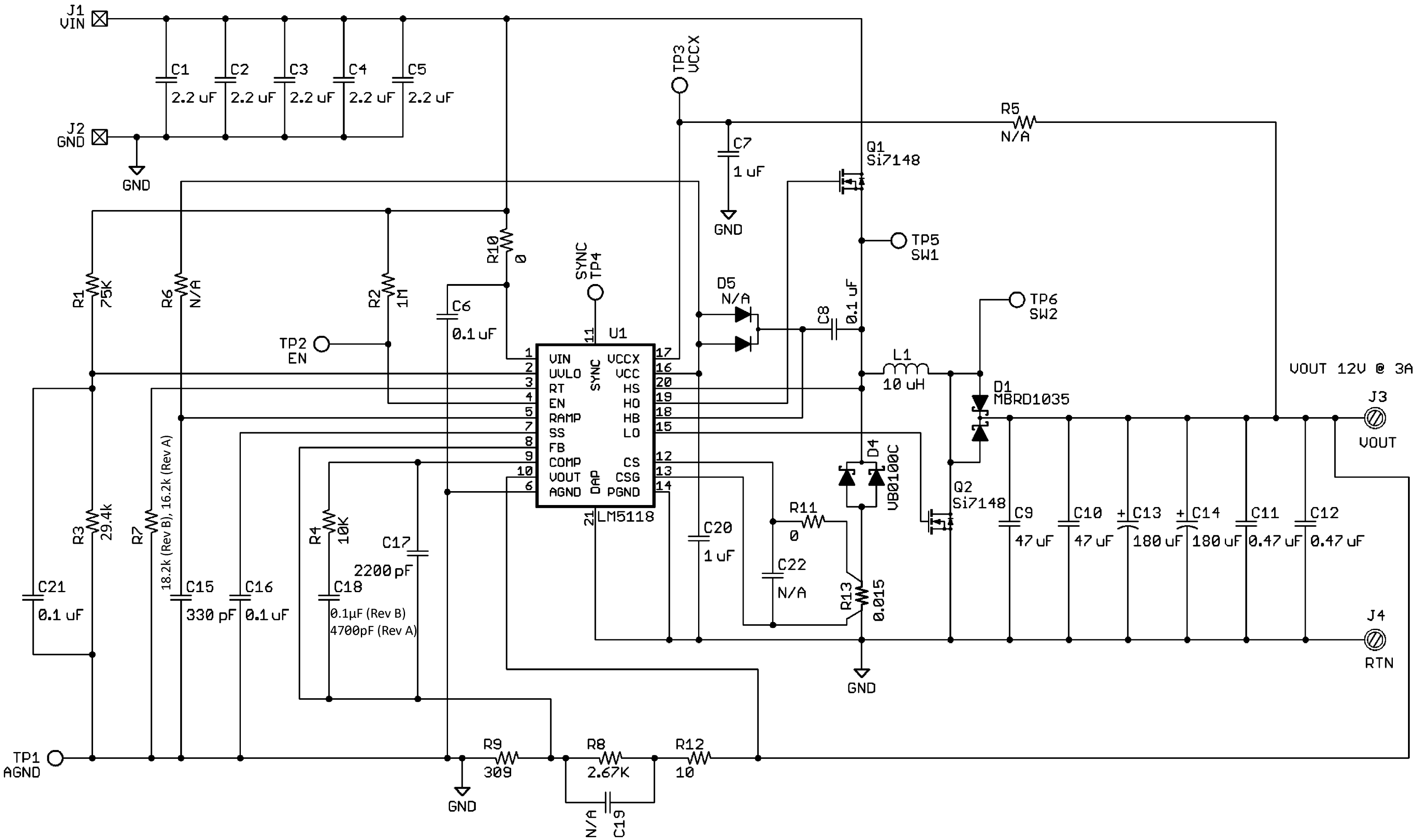


Figure 17. Evaluation Board Schematic

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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.

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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.

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

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

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

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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. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

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

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

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

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