LM5175RHF (QFN) EVM

User's Guide

Literature Number: SNVU518
April 2016

Contents

LM5175RHF (QFN) EVM User Guide

1 High Density EVM Description

The LM5175RHFEVM-HD demonstrates a compact buck-boost design using the LM5175 high performance 4-switch buck-boost controller. This evaluation module is designed to operate with input voltage from 5 V to 42 V and provide a regulated 12 V output with load current up to 6 A. The transition region control method of the LM5175 maintains high efficiency over the entire operating input voltage in contrast with a conventional four-switch buck-boost converter which has a drop in efficiency at V_{IN} close to V_{OUT}. The switching frequency is set at 400 kHz and can be synchronized to an external clock signal. The board specifications are listed in Table 1.

Table 1. Board Specifications

Parameter	Value
Input Voltage (V_{IN})	5.5V to 42V (45V transient)
Output Voltage (V_{OUT})	12V
Maximum Output Current (I_{OUT})	6A
Default Switching Frequency (f_{sw})	400 kHz
Synchronizable Frequency Range	Up to 600 kHz
Efficiency (I_{OUT} = 5A, V_{IN} = 6V to 36V)	95.1% to 98.4%
Board Size (6 layers)	50 mm x 43 mm (1.98 in x 1.7 in)

1.1 Additional Features

- Smooth Buck-Boost Operation
- Ultra-high (>98%) peak power conversion efficiency
- High power density compact design
- Adjustable output voltage using TRIM
- Resistor programmable switching frequency (adjustable) with optional external synchronization (SYNC) up to 600 kHz
- Cycle-by-cycle overcurrent protection via shunt resistor current sensing
- Optional hiccup mode overload protection (off by default)
- Default forced PWM (CCM) fixed switching operation with option to set diode emulation mode (DCM)
- Programmable V_{IN} UVLO threshold and hysteresis
- Spread spectrum dither option for reduced EMI
- Power Good indicator
- Input circuit damping and energy storage provided by bulk electrolytic capacitor
- Easy access to PGOOD, ENABLE, TRIM and SYNC using conveniently located test points

2 EVM Photos

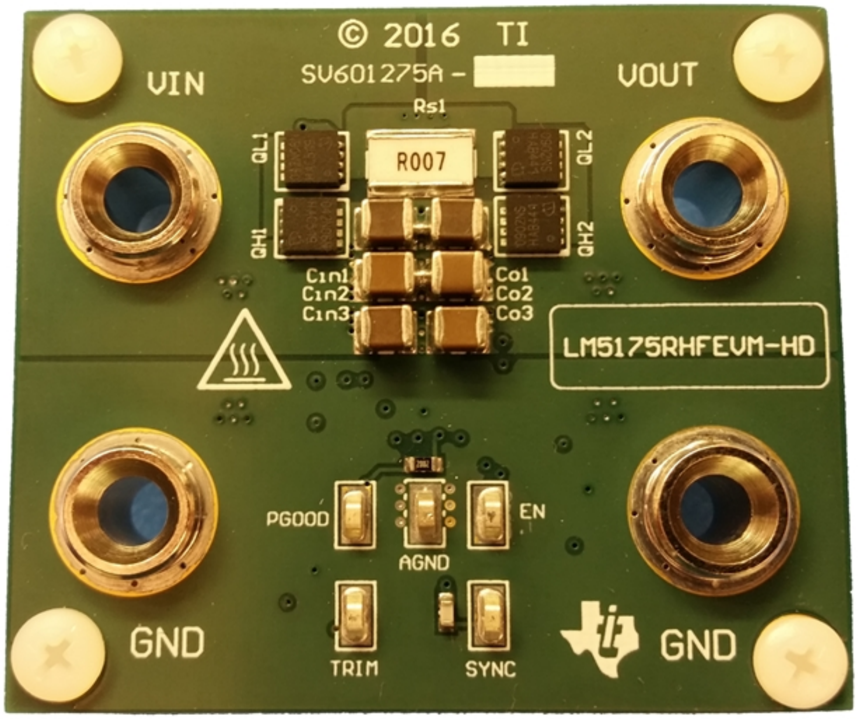

Figure 1. EVM Top Side

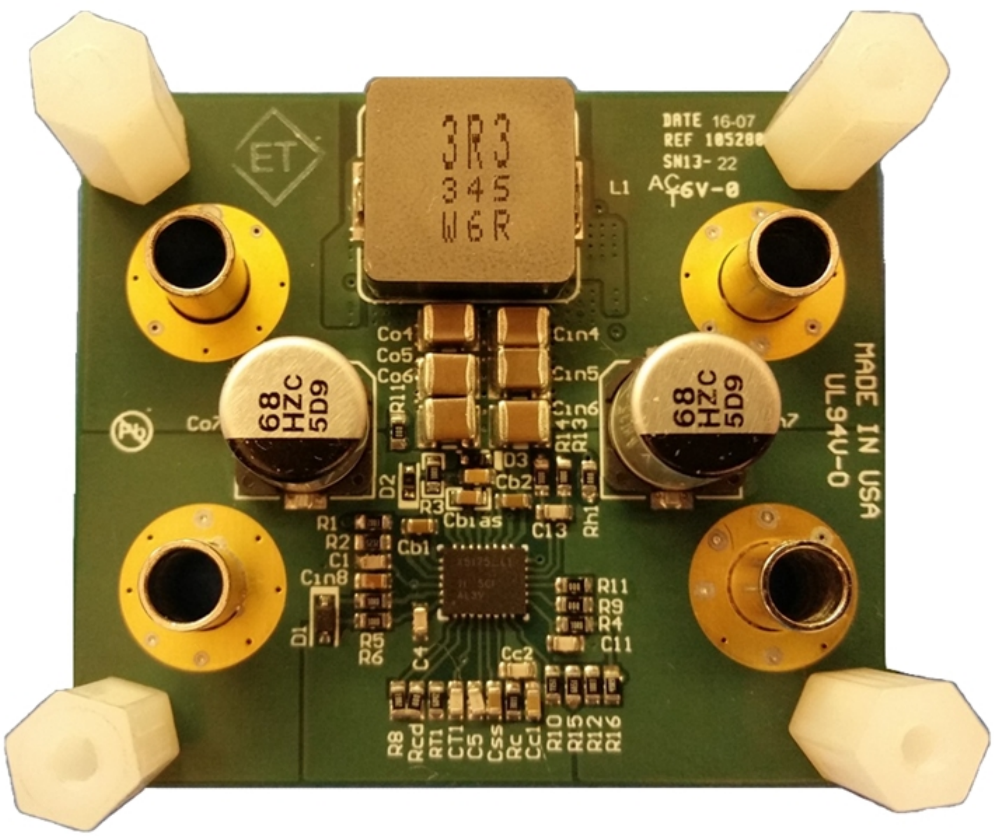

Figure 2. EVM Bottom Side

3 Signal Connections and Test Point Descriptions

3.1 Test Point Descriptions

Table 2. Test Point Descriptions

LABEL	DESCRIPTION
VIN	Input voltage positive power and sense connection
GND	Input voltage negative power and sense connection
VOUT	Output voltage positive power and sense connection
GND	Output voltage negative power and sense connection
AGND	Analog GND
SYNC	External frequency synchronization input (SYNC). This terminal is connected to the RT/SYNC pin of the LM5175 controller through a 100 pF capacitor on the board.
EN	ENABLE input; tie to GND to disable converter
PGOOD	Power Good output

3.2 Optional Configurations

Table 3. Optional Configurations

COMPONENT	DESCRIPTION
R8	R8 can be used to select DCM or CCM mode and for enabling hiccup mode current limit. See LM5175 device datasheet for R8 values. Default EVM configuration is CCM/No hiccup.
Rcd	Dither is disabled by default. Replace with an appropriate capacitor to enable dither. See LM5175 datasheet on how to set the dither frequency.

3.3 Signal Connections

3.3.1 Input Voltage Monitoring

The LM5175RHFEVM-HD provides two solder lug test points for measuring input voltage at the input banana connections. This allows the user to measure the actual input voltage without losses from input cables and connectors. All input voltage measurements should be made between VIN and GND test points.

3.3.2 Output Voltage Monitoring

The LM5175RHFEVM-HD provides two solder lug test points for measuring output voltage at the output banana connections. This facilitates measurement of the output voltage without losses related to output cables and connectors.

3.3.3 Power Good Voltage Output

The LM5175RHFEVM-HD provides a test point for measuring the PGOOD flag voltage. A 20-kΩ pullup resistor, Rpg, to VCC is included. For true open-drain operation with no pullup, remove Rpg. One possible scenario where a PGOOD pullup is not required involves PGOOD of an upstream converter connected to the EN input of a downstream converter to provide sequential startup of multiple regulators.

3.3.4 Enable Voltage Input

The LM5175RHFEVM-HD provides a test point for measuring the EN voltage. Shorting this test point to GND disables the converter. The EN/UVLO voltage should not exceed the input voltage.

3.3.5 SYNC Input

The LM5175RHFEVM-HD provides a test point for applying a synchronization (SYNC) input signal. The free-running switching frequency is set at 400 kHz by resistor RT1. However, the converter aligns in frequency and phase with that of the applied SYNC signal up to 600 kHz. If required, apply an external SYNC signal with a frequency higher than the internal free-running frequency as per the LM5175 device datasheet.

4 Test Setup and Procedure

Figure 3 shows the recommended test setup to evaluate the LM5175RHFEVM-HD. Working at an ESD workstation, make sure that any wrist straps, boot straps or mats are connected referencing the user to earth ground before power is applied to the EVM.

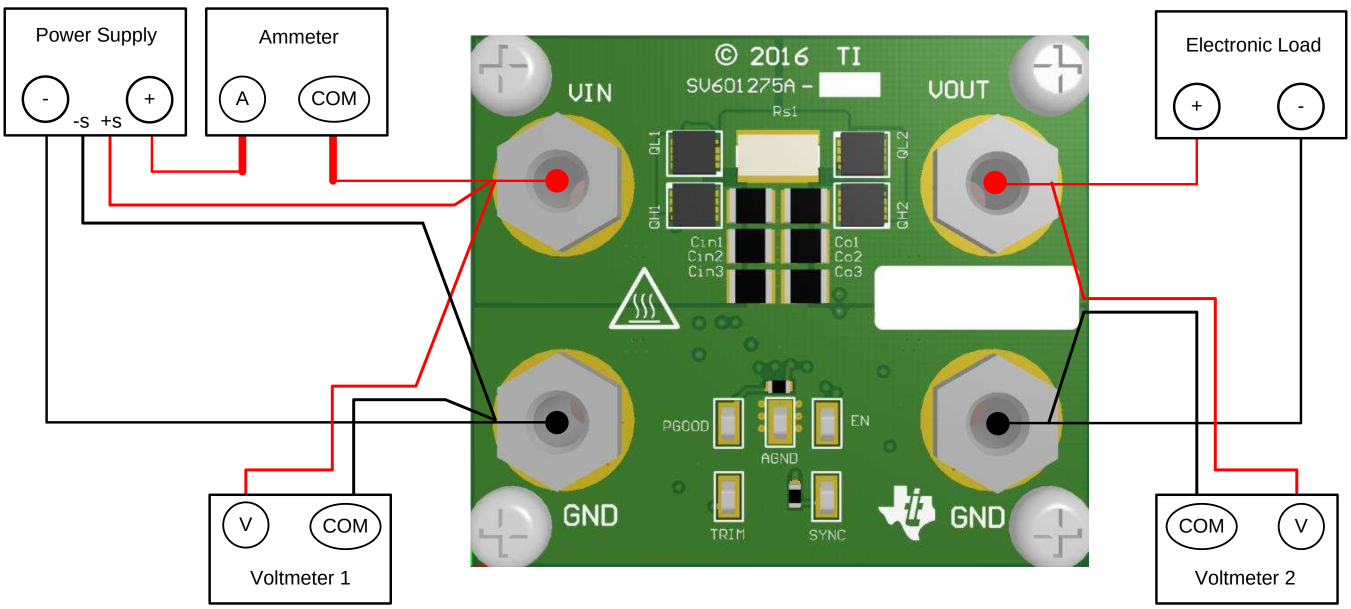

Figure 3. Test Setup Connection Diagram

4.1 Test Equipment

Voltage Source: The input voltage source VIN should be a 0–50-V dc source capable of supplying 15 A.

Multimeters:

- **Voltmeter 1:** Input voltage at VIN to GND
- **Voltmeter 2:** Output voltage at VOUT to GND
- **Ammeter:** Input current (or use the power supply readout if its accuracy is deemed acceptable)

Electronic Load: The output load should be an electronic constant-resistance or constant-current mode load capable of 0-10 A at 12 V.

Oscilloscope (optional): A digital or analog oscilloscope can be used to measure pertinent converter waveforms. With the scope set to 20-MHz bandwidth and AC coupling, the output voltage ripple can be measured directly across an output capacitor with a short ground lead normally provided with the scope probe. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the probe's ground barrel through the ground lead to the capacitor's negative terminal. It is not recommended to use a long leaded ground connection because this may induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed.

Fan: Depending on the EVM's operating conditions, the temperature rise of certain powertrain components can approach 50°C. Although not mandatory, use a small fan capable of 200–400 LFM to reduce component temperatures while the EVM is operating. Exercise care when touching the EVM while the fan is not running. Always use caution when touching any circuits that may be live or energized.

4.2 Recommended Test Setup

4.2.1 Input Connections

- Prior to connecting the DC input source, it is advisable to limit the source current to 10 A maximum. Make sure the input source is initially set to 0 V and connected to VIN and GND banana connections as shown in Figure 3. While the on-board hybrid electrolytic capacitor provides input circuit damping, an additional high-ESR input capacitor may be required if long input lines are used.
- Connect voltmeter 1 at VIN and GND test points to measure the input voltage.
- Connect ammeter to measure the input current.

4.2.2 Output Connections

- Connect an electronic load to VOUT and GND connections. Set the load to constant-resistance mode or constant-current mode at 0 Adc before applying input voltage. Use short load lines to minimize voltage drop to the load.
- Connect voltmeter 2 at VOUT and GND solder lugs to measure the output voltage.
- The output current level can be taken from the electronic load readout (if its accuracy is deemed acceptable).

4.3 Test Procedure

4.3.1 Line, Load Regulation and Efficiency

- Set up the EVM as described above.
- Set target load in the electronic load using either constant resistance or constant current mode.
- Increase input source from 0 V to 42 V, using voltmeter 1 to measure input voltage.
- Use voltmeter 2 to measure output voltage, V_{OUT}.
- Vary load from 0 to 6 Adc, V_{OUT} should remain within load regulation specification.
- Vary input source voltage from 5.5 V to 42 V, V_{OUT} should remain within line regulation specification.
- Decrease load to 0 A. Decrease input source voltage to 0 V to power down.

4.3.2 Control Loop Gain and Phase

The resistor R16 on the LM5175RHFEVM-HD is a convenient injection point for loop response analysis.

- Set up EVM as described previously.
- Connect isolation transformer secondary across R16.
- Connect output signal amplitude measurement probe (TEST) to VOUT and input signal amplitude measurement (REF) probe to opposite side of R16.
- Connect ground leads to the AGND test point as required.
- Apply 10 mV or less AC signal to the isolation transformer primary. Adjust amplitude as necessary.
- Sweep the frequency over the frequency range of interest (e.g. 100 Hz to 100 kHz) with 10 Hz or lower post filter.
- Measure the control loop gain and phase characteristic. Record the crossover frequency and phase margin.
- Disconnect isolation transformer before making other measurements (signal injection into the loop may interfere with the integrity of other measurements).

5 Test Data and Performance Curves

5.1 Efficiency

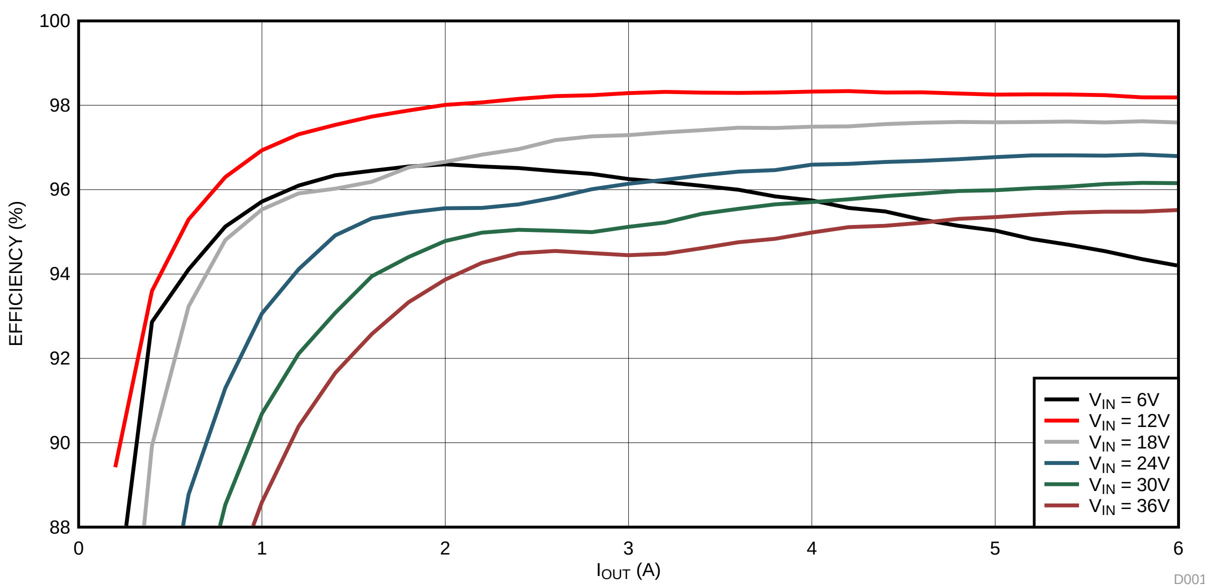

Figure 4. Efficiency vs. Output Current

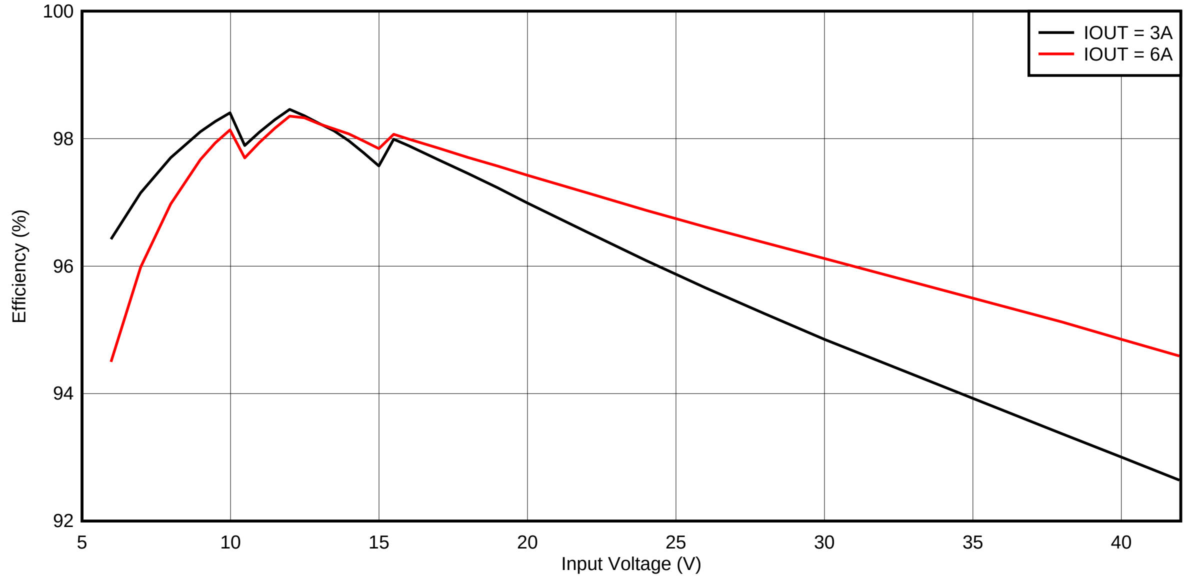

Figure 5. Efficiency vs Input Voltage

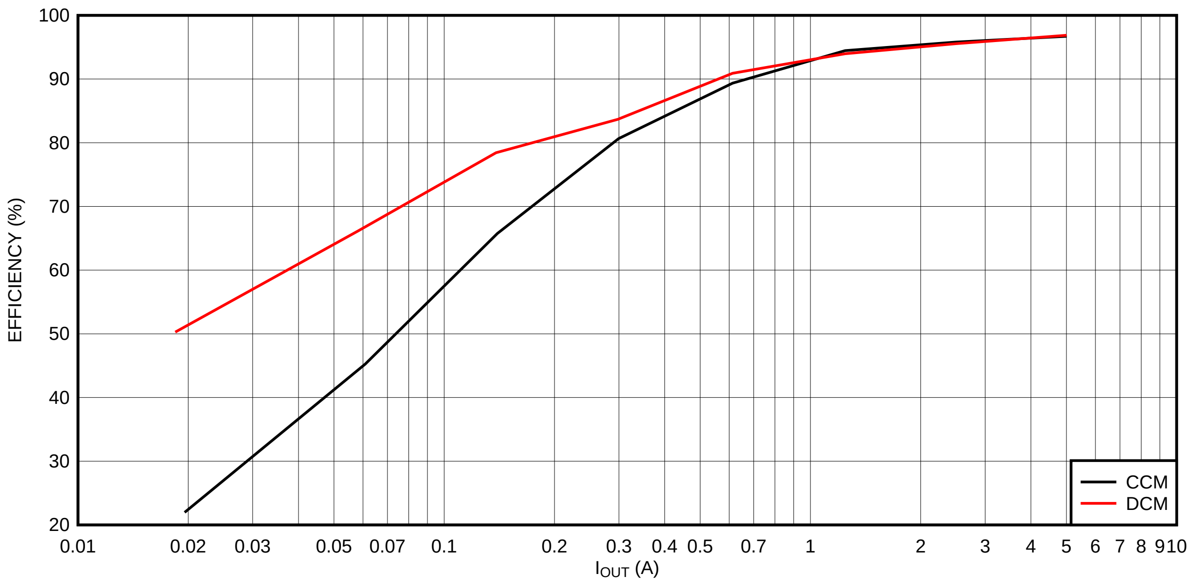

Figure 6. Efficiency vs Output Current for V_{IN} = 24 V

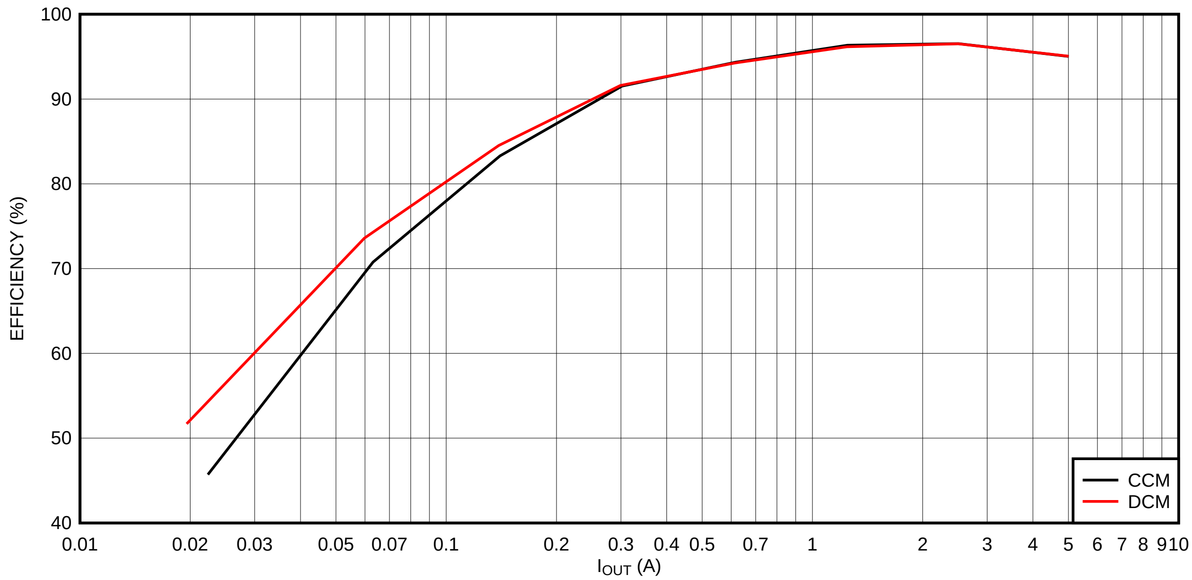

Figure 7. Efficiency vs Output Current for V_{IN} = 6 V

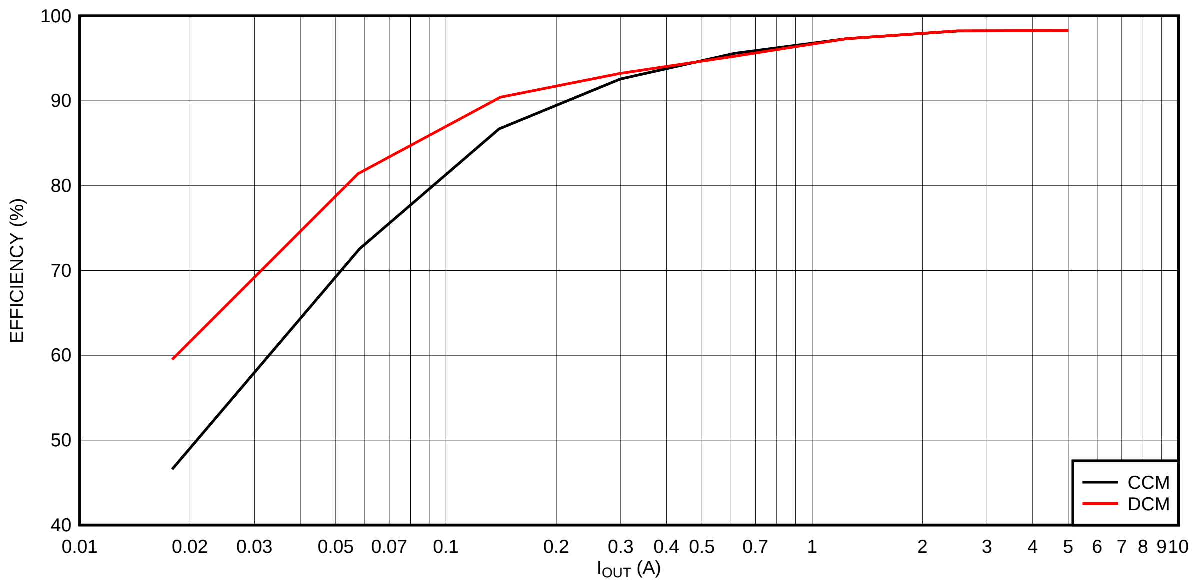

Figure 8. Efficiency vs Output Current for V_{IN} = 12 V

Table 4. No Load Input Current (IQ) vs Input Voltage

VIN	IQ (CCM)	IQ (DCM)
24V	35 mA	2.6 mA
12V	22 mA	12 mA
6V	58 mA	41 mA

5.2 Line and Load Regulation

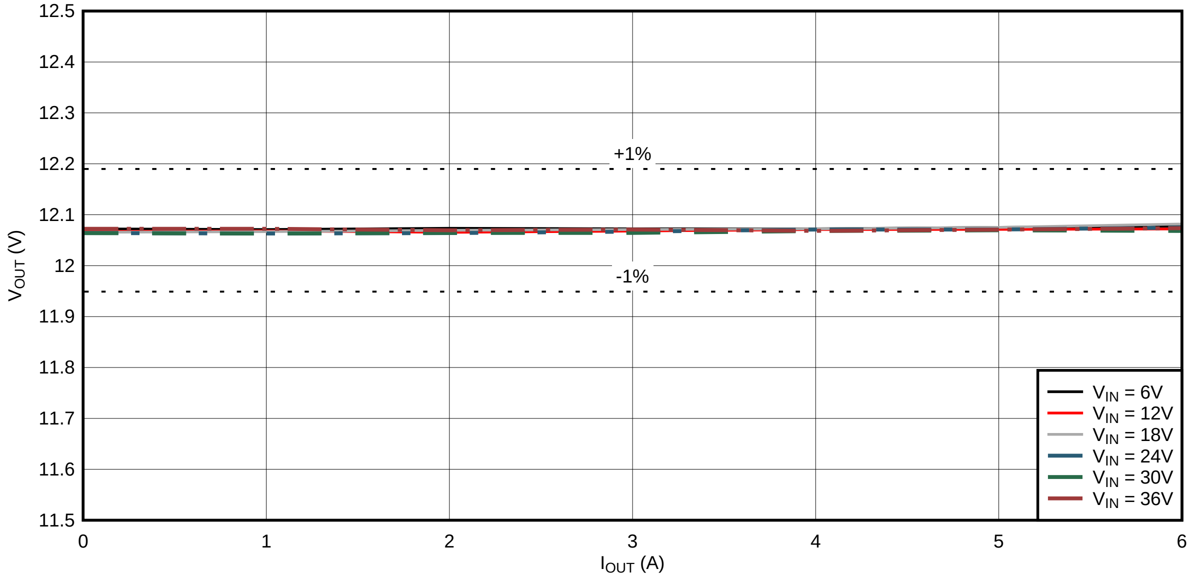

Figure 9. Line and Load Regulation

5.3 Bode Plots

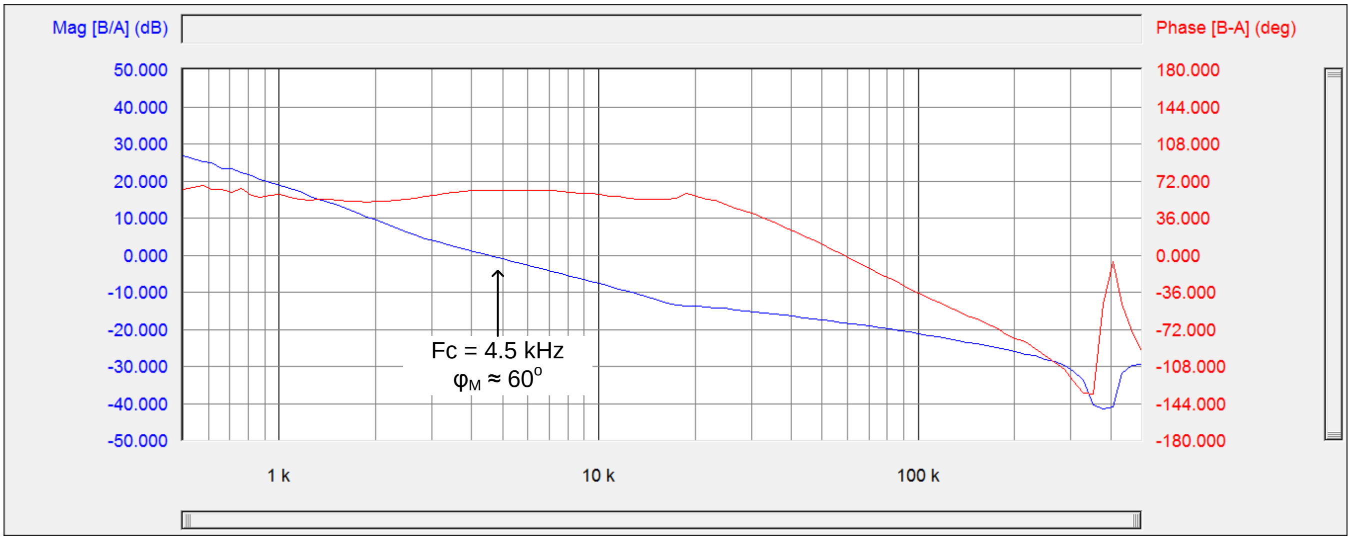

Figure 10. Bode Plot for V_{IN} = 6V, I_{OUT} = 3A

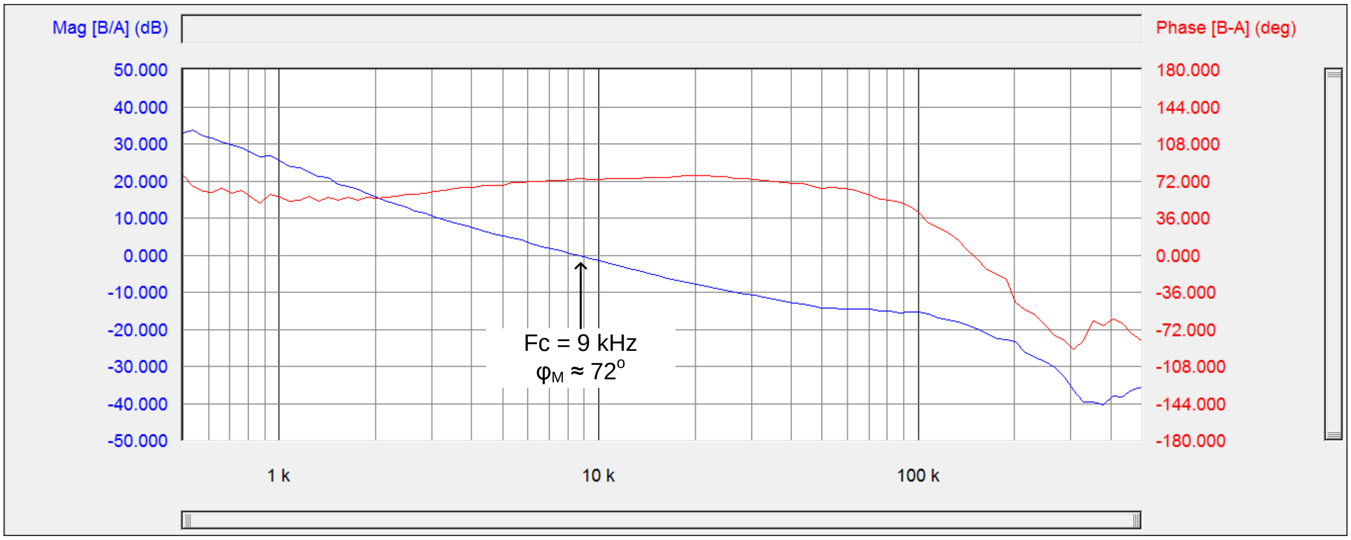

Figure 11. Bode Plot for V_{IN} = 12V, I_{OUT} = 3A

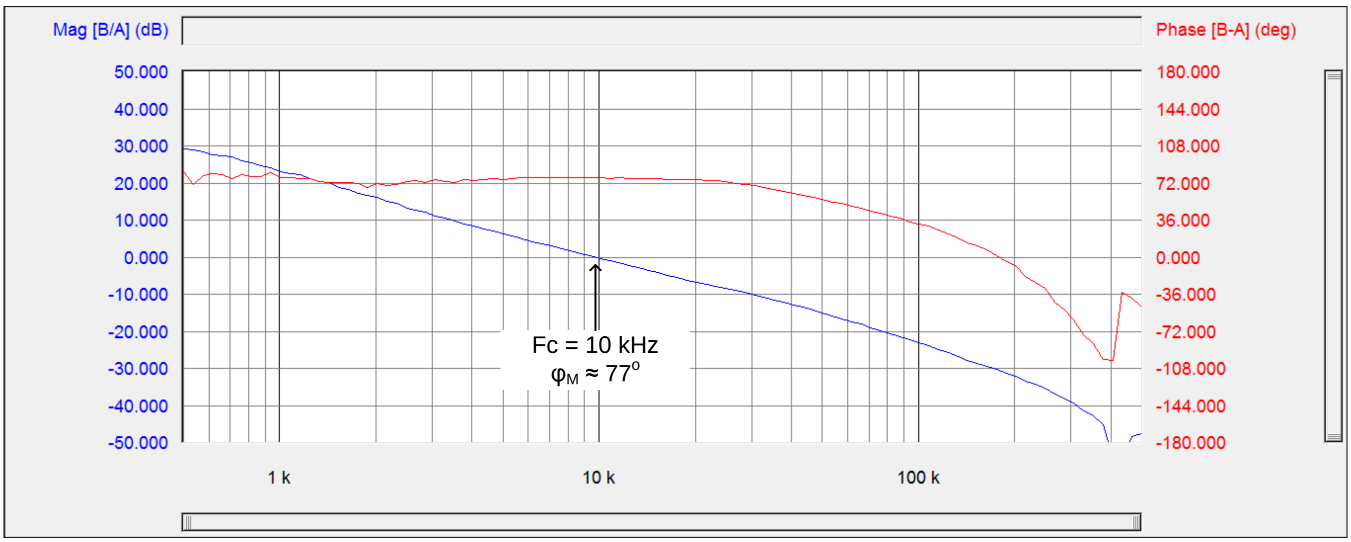

Figure 12. Bode Plot for V_{IN} = 24V, I_{OUT} = 3A

5.4 Operating Waveforms

5.4.1 Switch Node Voltages and Inductor Current

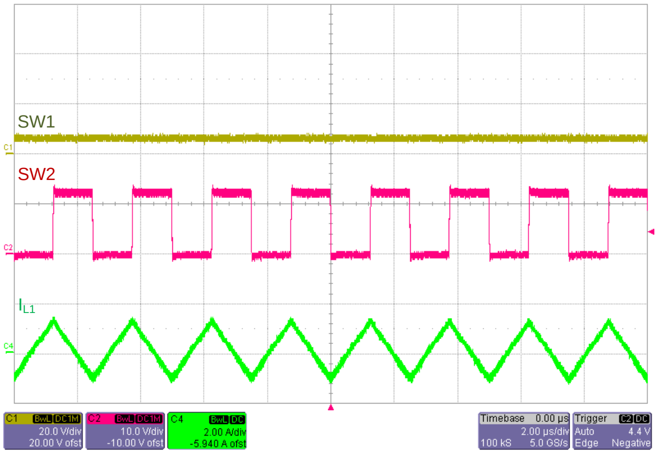

Figure 13. SW1, SW2, I_L Waveforms: V_{IN} = 6 V, V_{OUT} = 12 V, I_{OUT} = 0 A

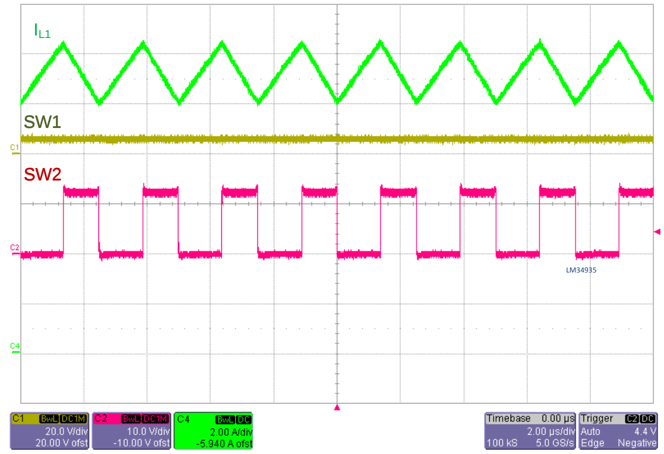

Figure 14. SW1, SW2, I_L Waveforms: V_{IN} = 6 V, V_{OUT} = 12 V, I_{OUT} = 5 A

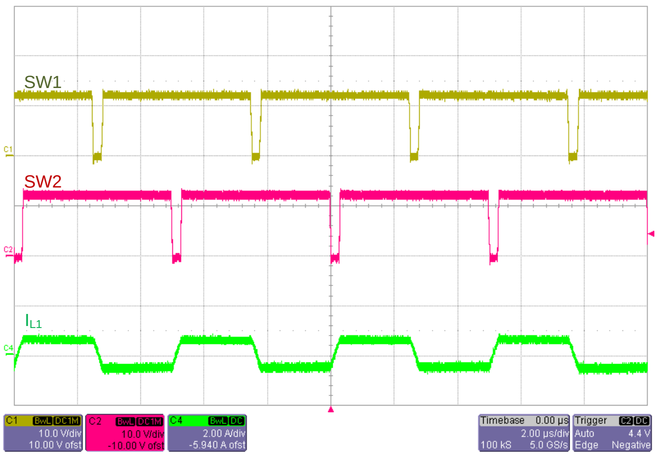

Figure 15. SW1, SW2, I_L Waveforms: V_{IN} = 12 V, V_{OUT} = 12 V, I_{OUT} = 0 A

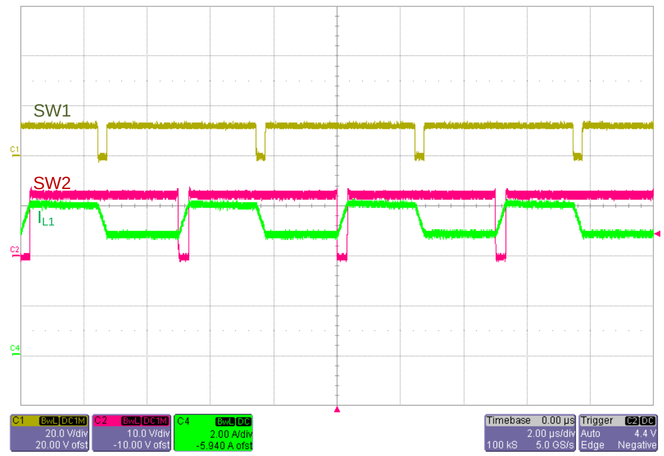

Figure 16. SW1, SW2, I_L Waveforms: V_{IN} = 12 V, V_{OUT} = 12 V, I_{OUT} = 5 A

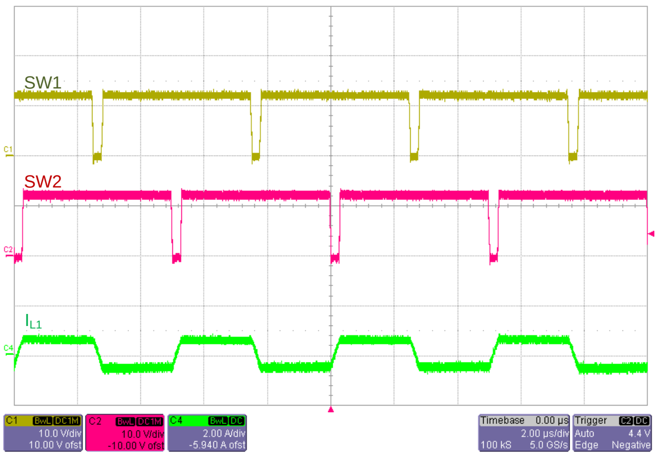

Figure 17. SW1, SW2, I_L Waveforms: V_{IN} = 16 V, V_{OUT} = 12 V, I_{OUT} = 0 A

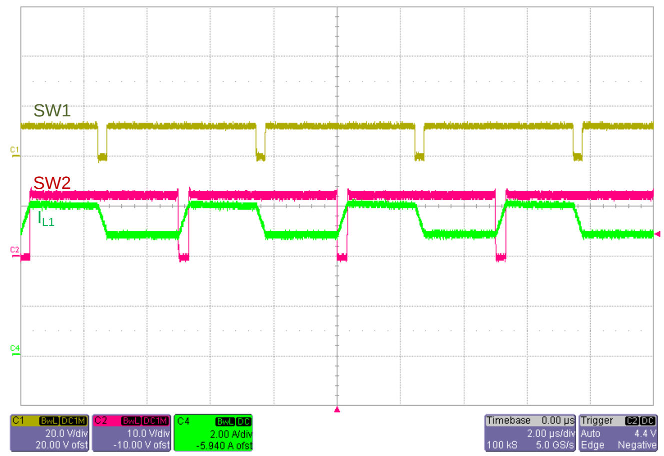

Figure 18. SW1, SW2, I_L Waveforms: V_{IN} = 16 V, V_{OUT} = 12 V, I_{OUT} = 5 A

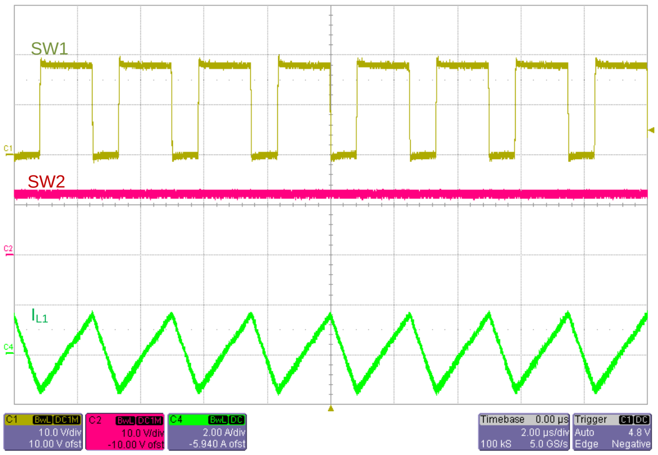

Figure 19. SW1, SW2, I_L Waveforms: V_{IN} = 18 V, V_{OUT} = 12 V, I_{OUT} = 0 A

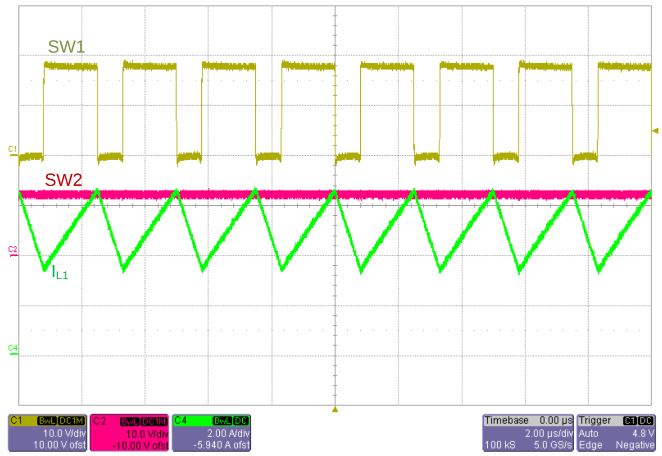

Figure 20. SW1, SW2, I_L Waveforms: V_{IN} = 18 V, V_{OUT} = 12 V, I_{OUT} = 5 A

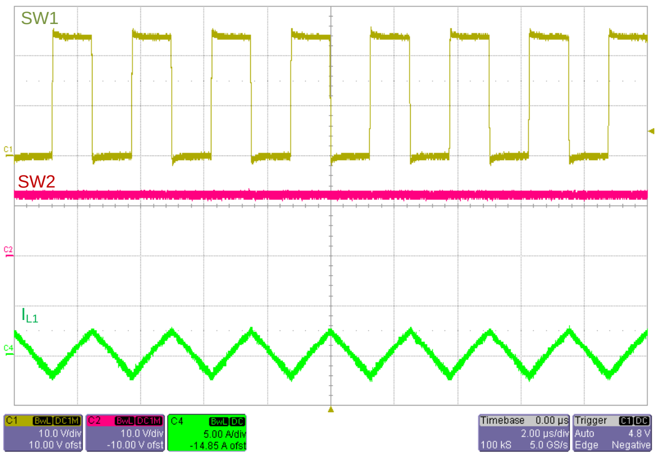

Figure 21. SW1, SW2, I_L Waveforms: V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 0 A

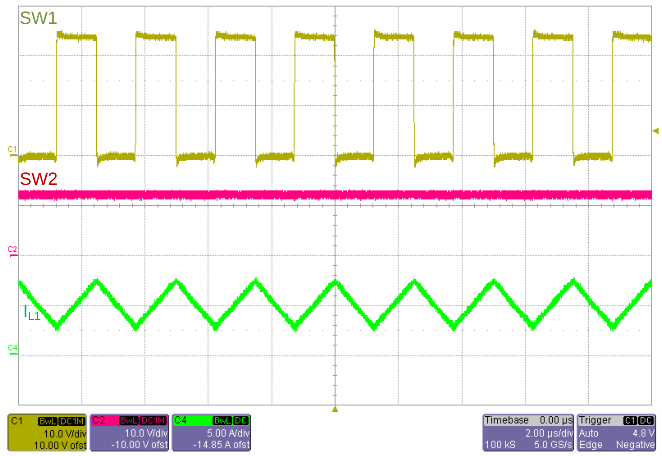

Figure 22. SW1, SW2, I_L Waveforms: V_{IN} = 24 V, V_{OUT} = 12 V, I_{OUT} = 5 A

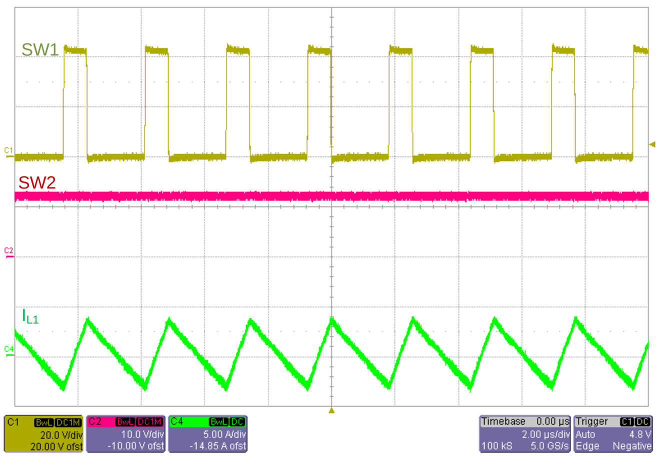

Figure 23. SW1, SW2, I_L Waveforms: V_{IN} = 42 V, V_{OUT} = 12 V, I_{OUT} = 0 A

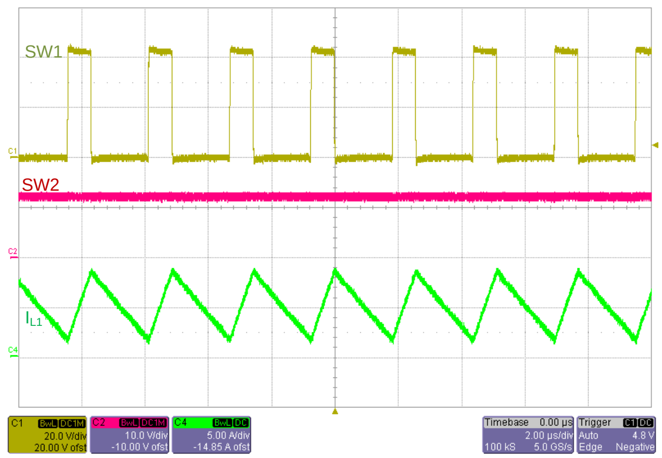

Figure 24. SW1, SW2, I_L Waveforms: V_{IN} = 42 V, V_{OUT} = 12 V, I_{OUT} = 5 A

5.4.2 Output Voltage Ripple, 20-MHz Bandwidth

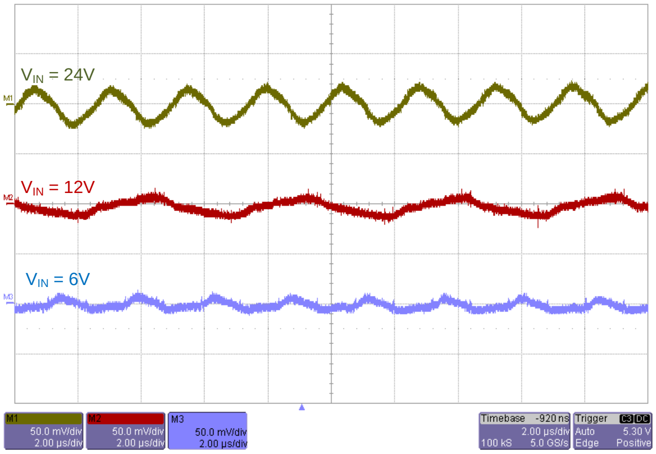

Figure 25. V_{OUT} Ripple, I_{OUT} = 0A

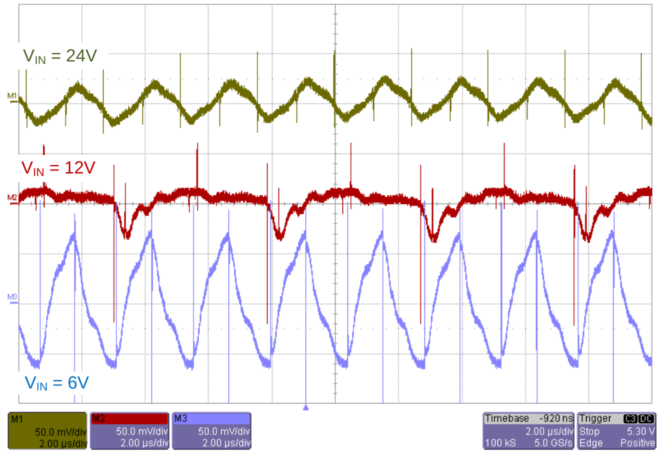

Figure 26. V_{OUT} Ripple, I_{OUT} = 5A

5.4.3 Startup Waveform

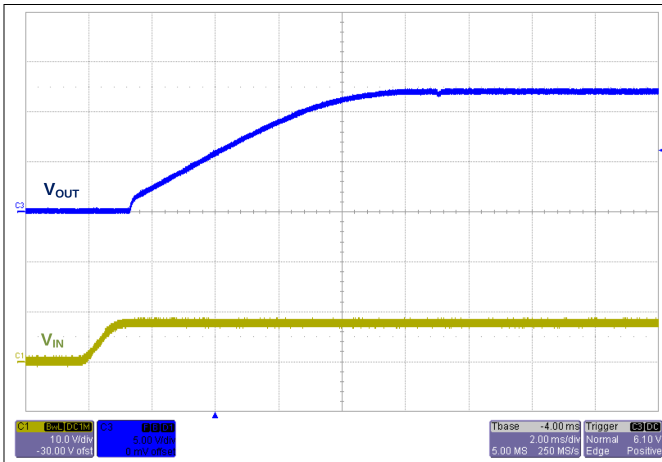

Figure 27. Startup at V_{IN} = 8 V, I_{OUT} = 0A

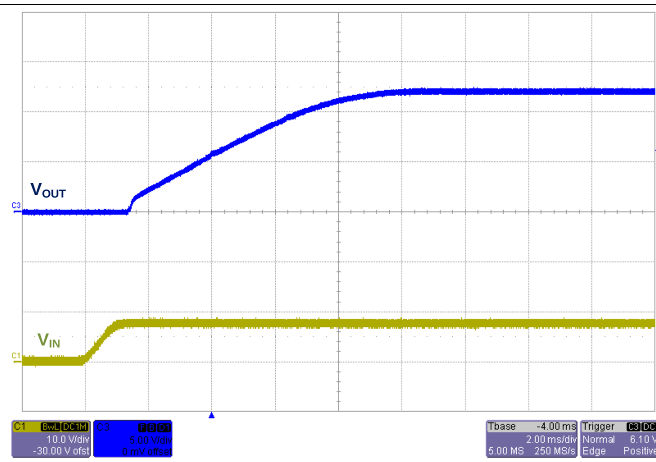

Figure 28. Startup at V_{IN} = 8 V, I_{OUT} = 4A

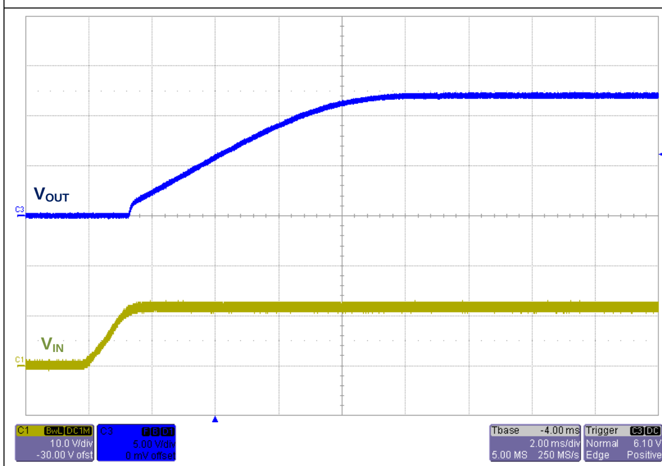

Figure 29. Startup at V_{IN} = 12 V, I_{OUT} = 0A

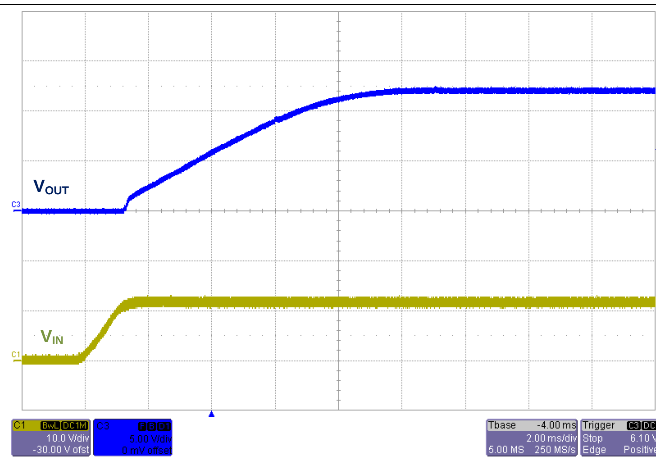

Figure 30. Startup at V_{IN} = 12 V, I_{OUT} = 4A

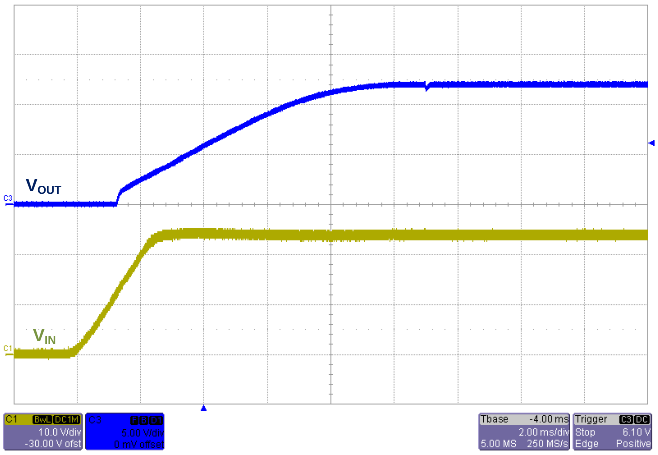

Figure 31. Startup at V_{IN} = 24 V, I_{OUT} = 0A

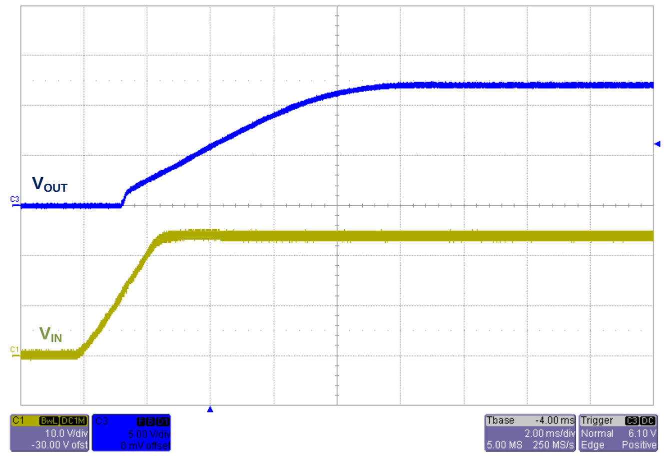

Figure 32. Startup at V_{IN} = 24 V, I_{OUT} = 4A

6 EVM Documentation

6.1 Schematic

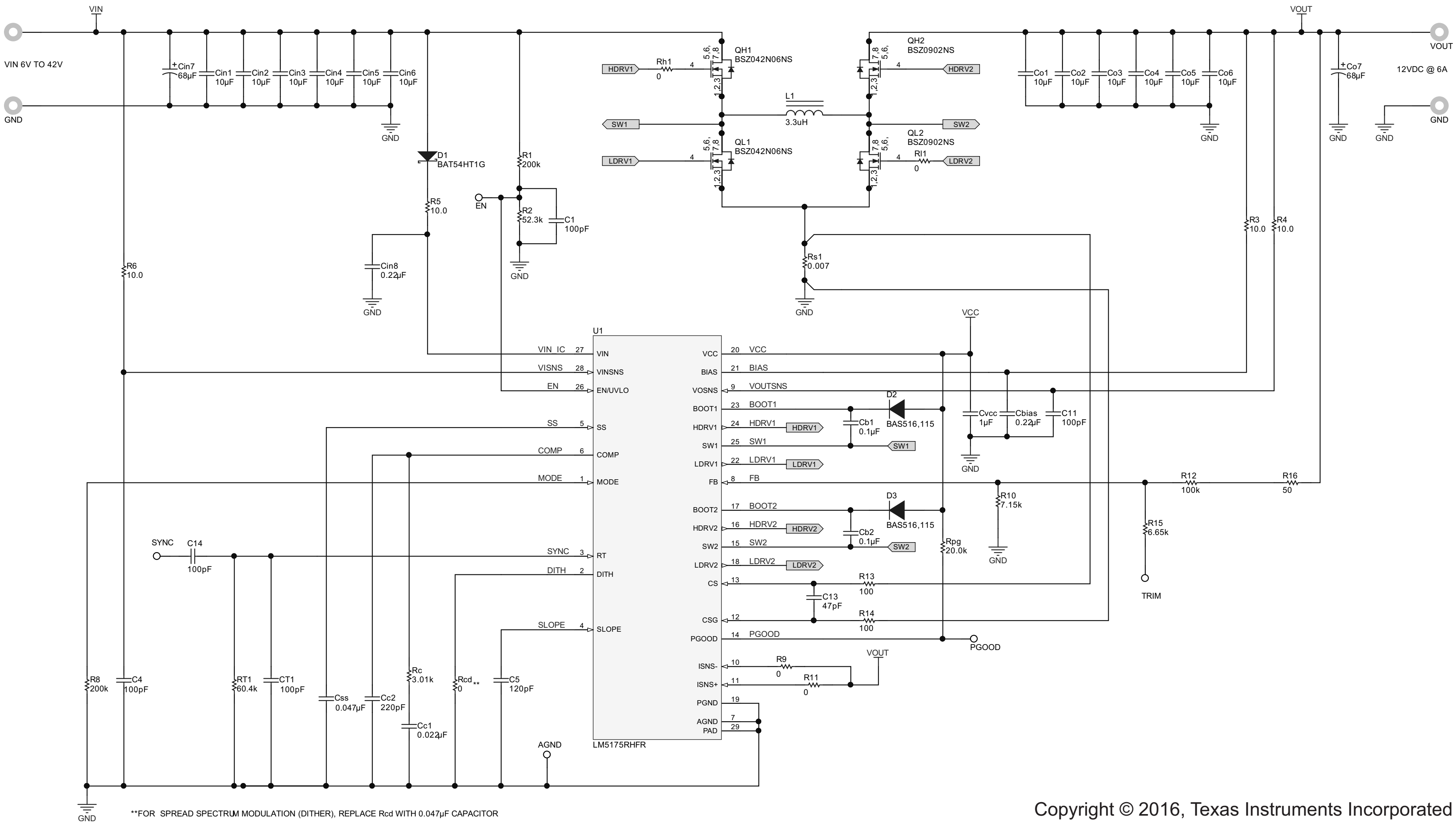

Figure 33. EVM Schematic

6.2 PCB Layout

Figure 34 through Figure 41 show the design of the LM5175 6-layer PCB with 2-oz copper thickness. The EVM is a two-sided design, and it includes positions for input and output bulk capacitors.

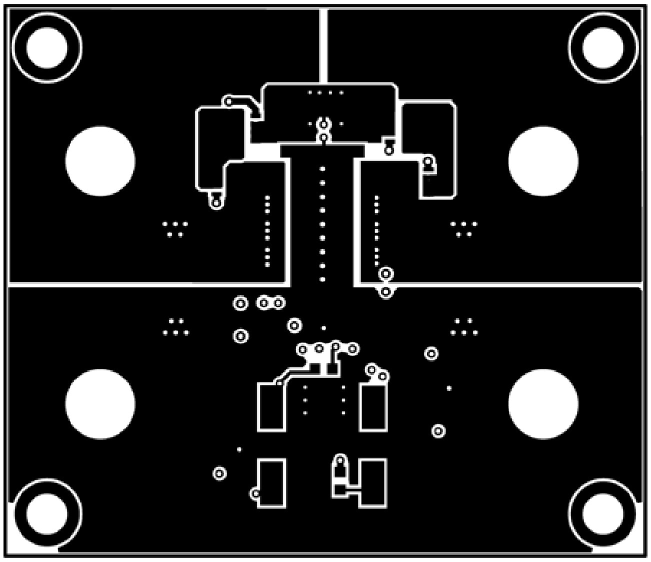

Figure 34. Top Copper (Top View)

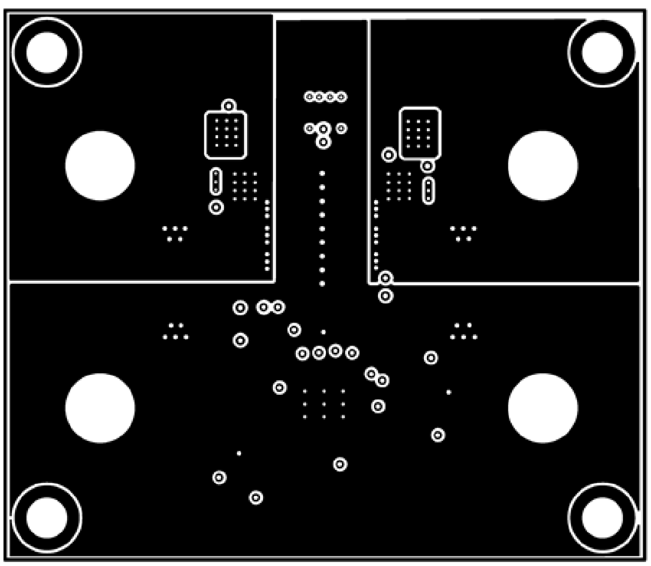

Figure 35. Layer 2 (Top View)

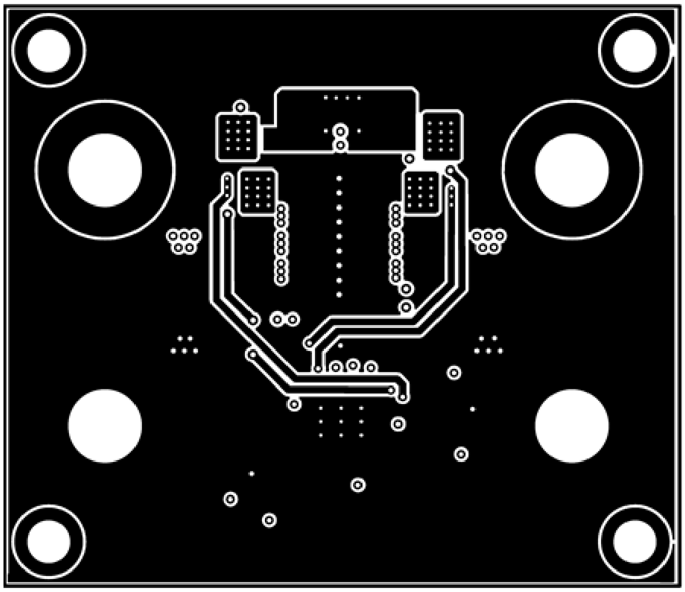

Figure 36. Layer 3 (Top View)

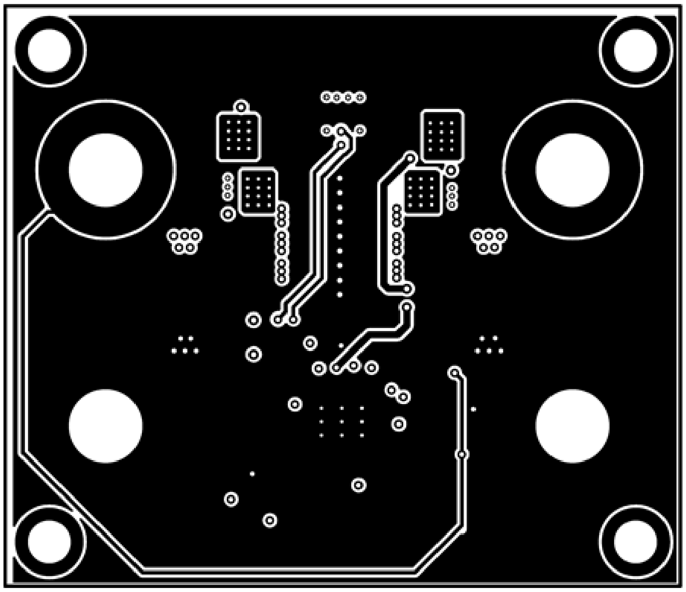

Figure 37. Layer 4 (Top View)

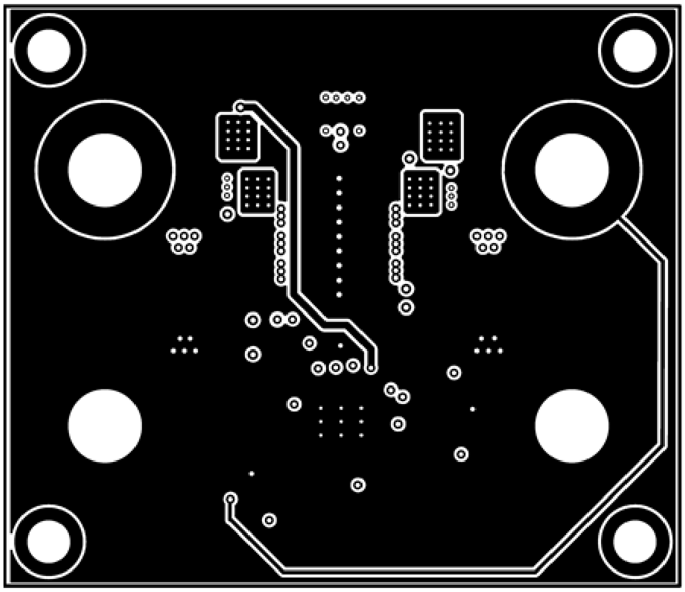

Figure 38. Layer 5 (Top View)

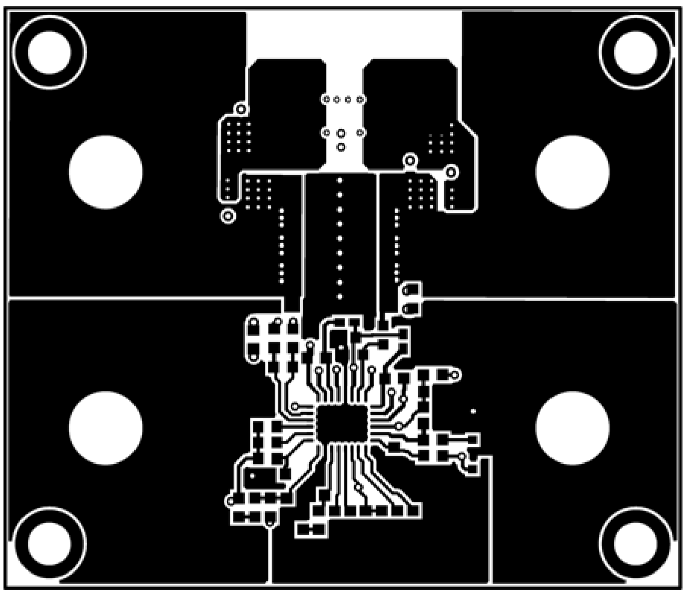

Figure 39. Bottom Copper (Bottom View)

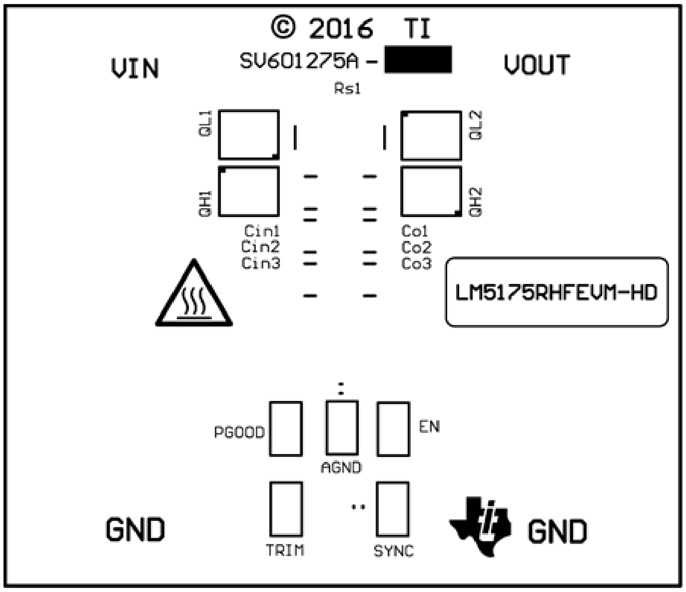

Figure 40. Top Layer Silkscreen (Top View)

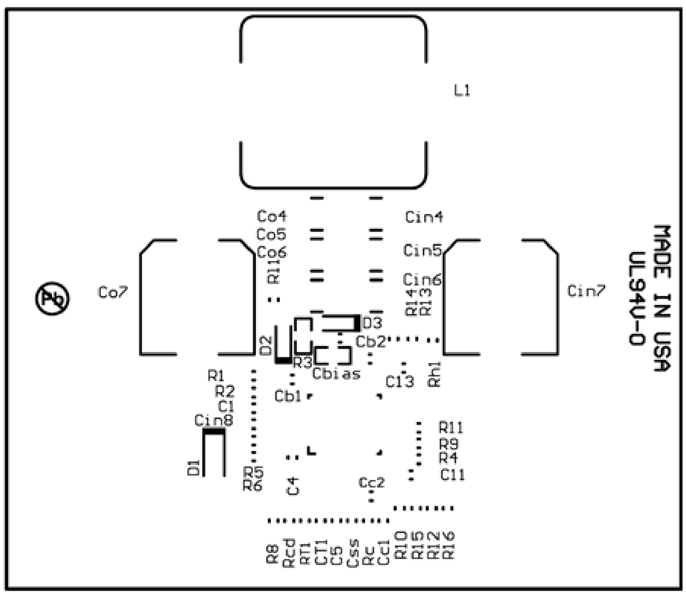

Figure 41. Bottom Layer Silkscreen (Bottom View)

6.3 Bill of Materials

Table 5. Bill of Materials

Count	Ref Des	Description	Part Number	MFR
4	C1, C4, C11, CT1	Capacitor, Ceramic, 100pF, 50V, C0G, 5%, 0603	Std	Std
1	Cc1	Capacitor, Ceramic, 22nF, 25V, X7R, 10%, 0603	Std	Std
1	Cc2	Capacitor, Ceramic, 220pF, 50V, C0G, 5%, 0603	Std	Std
1	Css	Capacitor, Ceramic, 33nF, 25V, X7R, 10%, 0603	Std	Std
1	C5	Capacitor, Ceramic, 120pF, 50V, C0G, 5%, 0603	Std	Std
1	C13	Capacitor, Ceramic, 47pF, 50V, C0G, 5%, 0603	Std	Std
1	C14	Capacitor, Ceramic, 2.2nF, 50V, X7R, 10%, 0603	Std	Std
2	Cb1, Cb2	Capacitor, Ceramic, 0.1µF, 25V, X7R, 10%, 0603	Std	Std
2	Cbias, Cin8	Capacitor, Ceramic, 0.22µF, 50V, X7R, 10%, 0603	Std	Std
12	Cin1, Cin2, Cin3, Cin4, Cin5, Cin6, Co1, Co2, Co3, Co4, Co5, Co6	Capacitor, Ceramic, 10µF, 50V, X7S, 10%, 1210	GRM32EC71H106KA03L	Murata
			CGA6P3X7S1H106K250AE	TDK
		Capacitor, Ceramic, 10µF, 50V, X7R, 10%, 1210	C1210C106K5RACTU	Kemet
			GRM32ER71H106KA12L	Murata
			UMK325AB7106KM-T	Taiyo Yuden
2	Cin7, Co7	Capacitor, AL, 68µF, 50V, 20%, 30mΩ, 4000hr	EEHZC1H680P	Panasonic
			NSPE-Z680M50V8X10	NIC Components
1	Cvcc	Capacitor, Ceramic, 1µF, 25V, X7R, 10%, 0603	GRM188R71C105KA12D	Murata
1	D1	Diode Schottky, 30V, 200mA, SOD-323	BAT54HT1G	On Semi
2	D2, D3	Diode, 100V, 0.2A, SOD-523	BAS516	NXP
1	L1	Inductor, 3.3µH, 7.7mΩ DCR, 15A Irms, 32A Isat	PIMC135T-3R3MF	Delta
		Inductor, 3.3µH, 3.4mΩ DCR, 15A Irms, 29A Isat	74439369033	Wurth
2	QH1, QL1	MOSFET, N-Channel, 60V, 40A, PG-TSDSON-8	BSZ042N06NS	Infineon
2	QH2, QL2	MOSFET, N-Channel, 30V, 40A, PG-TSDSON-8	BSZ0902NS	Infineon
2	R1, R8	Resistor, Chip, 200kΩ, 1/10W, 1%, 0603	Std	Std
1	R2	Resistor, Chip, 52.3kΩ, 1/10W, 1%, 0603	Std	Std
5	R3, R4, R5, R6, R16	Resistor, Chip, 10Ω, 1/10W, 1%, 0603	Std	Std
1	R10	Resistor, Chip, 7.15kΩ, 1/10W, 1%, 0603	Std	Std
1	R12	Resistor, Chip, 100kΩ, 1/10W, 1%, 0603	Std	Std
2	R13, R14	Resistor, Chip, 100Ω, 1/10W, 1%, 0603	Std	Std
1	R15	Resistor, Chip, 6.65kΩ, 1/10W, 1%, 0603	Std	Std
1	Rpg	Resistor, Chip, 20kΩ, 1/10W, 1%, 0603	Std	Std
1	Rc	Resistor, Chip, 3.01kΩ, 1/10W, 1%, 0603	Std	Std
3	Rh1, Rl1	Resistor, Chip, 0Ω, 1/10W, 5%, 0603	Std	Std
1	Rs1	Resistor, 7mΩ, 3W, 1%, 2512 WIDE	KRL6432E-M-R007	Susumu
			CSR1225FK07L0	Stackpole
			LRF3WLF-01-R007	TT Electronics
1	RT1	Resistor, Chip, 60.4kΩ, 1/10W, 1%, 0603	Std	Std
1	U1	IC, Synchronous Buck-Boost Controller, TSSOP-28	LM5175PWP	TI
1	PCB1	PCB, FR4, 6 layer, 2 oz, 50 mm x 43 mm	PCB	Any
4	VIN, VOUT, GND, GND	Banana Jack Power Terminal with Solder Lug	108-0740-001	Emerson
4	H3, H4, H7, H8	Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F
4	H1, H2, H5, H6	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
5	AGND, EN, TRIM, PGOOD, SYNC	Test Point, SMT	5016	Keystone

Revision History

DATE	REVISION	NOTES
April 2016	*	Initial release.

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

3 *Regulatory Notices:*

   3.1 *United States*

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

   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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-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.

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。 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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

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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。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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 WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (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 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 AND CONDITIONS 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 MADE, CONCEIVED OR ACQUIRED PRIOR TO OR AFTER DELIVERY OF THE EVM.

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 AND CONDITIONS. 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 ANDCONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, 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 ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS 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