User's Guide

LM5123EVM-BST Evaluation Module

ABSTRACT

The LM5123EVM-BST evaluation module showcases the features and performance of the LM5123-Q1 wide input voltage synchronous boost controller. The standard configuration is designed to provide a regulated output of 24 V at 100 W, from an input voltage of 9 V to 18 V and switching at 440 kHz. The output voltage can be dynamically modified up to 45 V at 100 W using the TRK pin of the LM5123-Q1.

This EVM is designed for ease of configuration, enabling a user to evaluate many different applications on the same module. Functionality includes; low I_Q operation, internal feedback resistors, bypass mode operation when V_{IN} is greater than V_{OUT}, dynamic output voltage tracking, power good (PGOOD) indicator, programmable frequency dithering, programmable undervoltage lock out (UVLO), and overvoltage protection.

Table of Contents

List of Figures

List of Tables

Trademarks

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1 Introduction

The LM5123EVM-BST evaluation module is designed to evaluate the operation and performance of the LM5123-Q1 low-I_Q synchronous boost controller. The EVM operates over an input voltage range of 9 V to 18 V and can handle input transients up to 42 V. The EVM provides a 24-V output with a maximum power rating of 100 W. The output voltage can be changed to 45 V while support a 100-W output using the TRK pin of the LM5123-Q1. The EVM offers a large range of configurable components and connections to evaluate the LM5123-Q1 for many applications. Figure 1-1 shows the standard application circuit for the LM5123EVM-BST evaluation module.

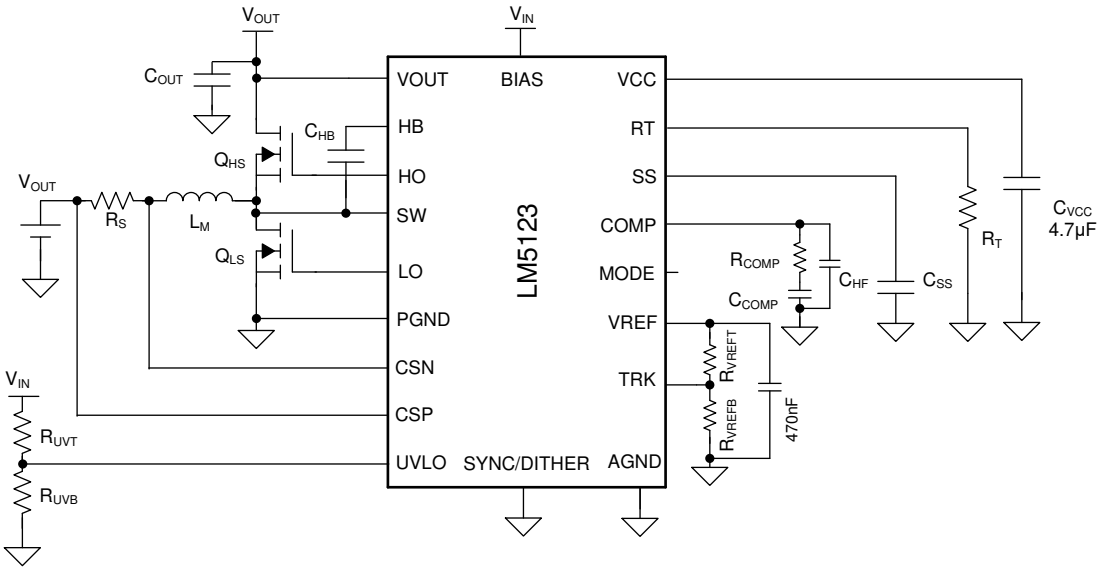

Figure 1-1. Typical Application Circuit

1.1 Applications

- Automotive audio power supply with tracking
- Automotive LED bias supply
- Automotive HVAC controller supply
- Automotive motor power supply

1.2 Features

The LM5123EVM-BST has the following features:

- Input voltage range from 9 V to 18 V
- Internal low leakage current high-impedance feedback resistors with programmable output voltage
- Operating frequency of 440 kHz with externally clock synchronization up or down by 20%
- Output voltage tracking using the TRK pin of the LM5123-Q1
  - See Section 2.3.1 for more details on tracking
- Bypass mode operation when V_{IN} is greater than V_{OUT}
- Selectable forced-PWM (FPWM), Skip mode, or diode emulation using the MODE pin
- High power conversion efficiency across a wide operating range
  - Full-load efficiency of greater then 97% at V_{IN} = 13.5 V, V_{OUT} = 24 V, P_{OUT} = 100 W
- Cycle-by-cycle peak current limiting
- Optional frequency dithering for improved EMI performance
- Power good indicator
- Programmable soft-start time
- Programmable line undervoltage lockout (UVLO)

2 EVM Setup

Section 2 describes the operating conditions for the EVM, as well as the configuration points of the evaluation module.

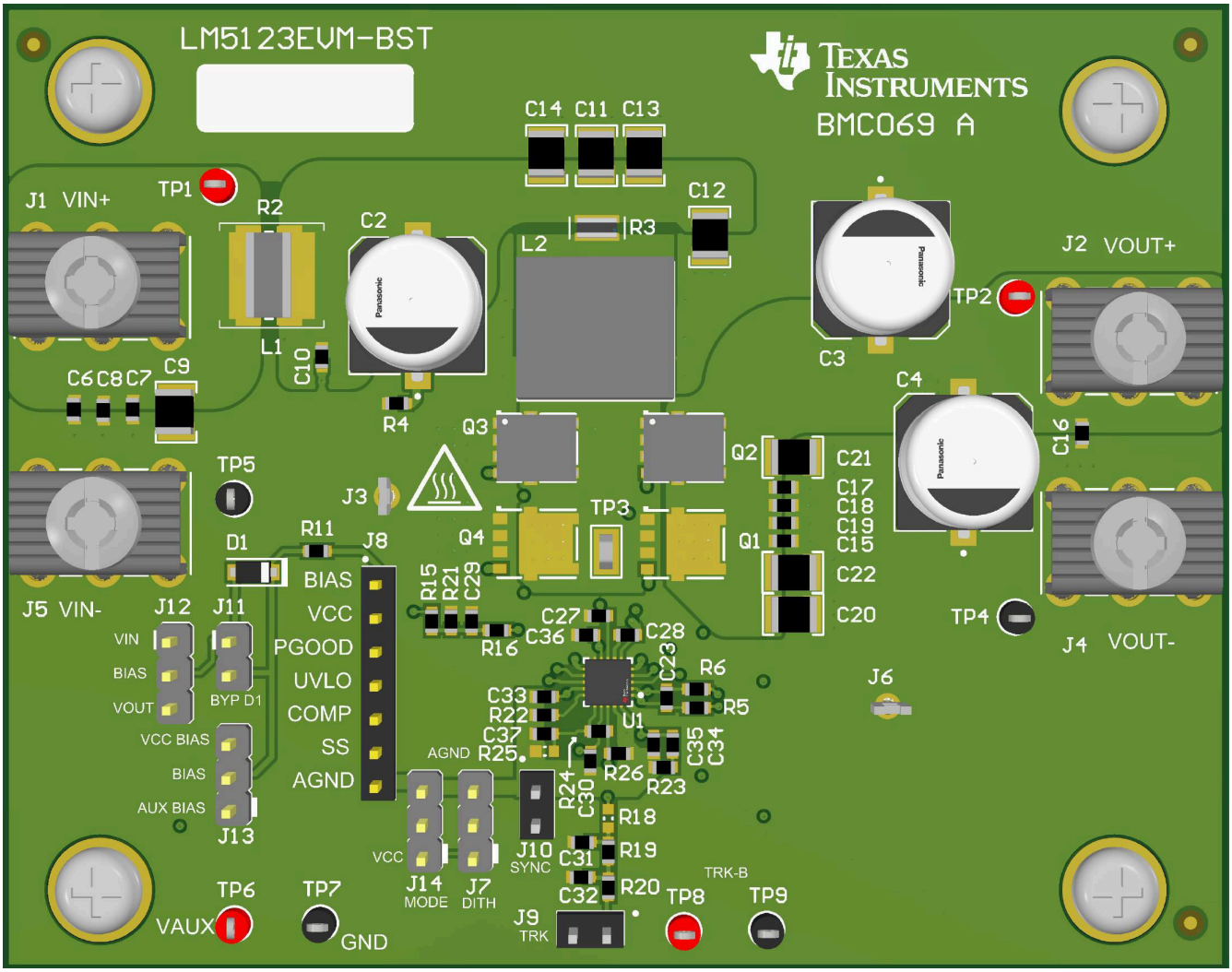

Figure 2-1. EVM Photo

CAUTION
Prolonged operation with low input at full power will cause heating of Q3 and Q2. Board surface is hot. Do not touch! Contact may cause burns.

2.1 EVM Characteristics

Table 2-1 details the EVM characteristics.

Table 2-1. EVM Characteristics

Parameter	Test Condition		MIN	TYP	MAX	UNIT
INPUT VOLTAGE CHARACTERISITCS						
Input Voltage Range	Operation		9	13.5	36	V
	UVLO voltage levels	Turn-off		7		V
		Turn-on		8		V
Input Current	No load operation, V_{IN} = 13.5 V, V_{OUT} = 24V, J14 = Open, UVLO = BIAS, R21 = Open				35	µA
OUTPUT CHARACTERISITICS						
Output Voltage	V_{TRK} = 400 mV			24		V
	V_{TRK} = 750 mV			45		V
Output Power					100	W
SYSTEM CHARACTERISITCS						
Switching Frequency				440		kHz
Full Load Efficiency	V_{IN} = 13.5 V, V_{OUT} = 24 V			97.6		%

2.2 EVM Connectors and Test Points

Section 2.2 describes the connection points of the evaluation module. Table 2-2 to Table 2-4 describe these connections. Table 2-2 lists the power connections of the evaluation module. These connections are intended to handle relatively large currents.

Table 2-2. Power Connections

Jumper	Pin	Description
J1	VIN+	Positive input voltage power for the evaluation module
J2	VOUT+	Positive output voltage power for the evaluation module
J4	GND	Negative output voltage power for the evaluation module
J5	VIN-	Negative input voltage power for the evaluation module

Table 2-3 lists the EVM jumpers and test points that configure the LM5123-Q1 as desired. These jumpers can set different modes of operation or provide signals to different pins of the LM5123-Q1.

Table 2-3. Programmable Jumper Connections

Jumper	Pins	Description	Default Connection
J7	Pin 1 to Pin 2	SYNC/DITHER/VH/CP is pulled to VCC through a 1-kΩ resistor to enable the internal charge pump or enable the VCC hold up functionality. This connection should not be made if the J10 is populated	
	Pin 2 to Pin 3	SYNC/DITHER/VH/CP is pulled to AGND through a 1-kΩ resistor to disable the internal charge-pump and VCC hold up functionality	
	Open	If using an external clock synchronization on J10, leave this jumper open.	X
J9	VTRK_D	PWM signal applied through a two stage low pass filter to the TRK pin. R18 must be populated.	
J10	Pin 1 to Pin 2	SYNC/DITHER/VH/CP pulled to ground disabling dithering, internal charge-pump functionality and VCC hold up functionality. Should not be populated when J7 is populated between pin 1 and pin 2	X
	Open	Dithering is enabled. To synchronize to an external clock C33 should be removed.	

Table 2-3. Programmable Jumper Connections (continued)

Jumper	Pins	Description	Default Connection
J11	Pin 1 to Pin 2	Bypass D1 to tie either the V_{IN} or V_{OUT} nets to the BIAS pin	X
	Open	Either V_{IN} or V_{OUT} is supplied through D1 to the BIAS pin	
J12	Pin 1 to Pin 2	V_{IN} is supplied to the BIAS pin. This is the default connection	X
	Pin 2 to Pin 3	V_{OUT} is supplied to the BIAS pin	
J13	Pin 1 to Pin 2	Connect an auxiliary power supply can be used to supply power to the BIAS pin. J11 should be open if this is populated	
	Pin 2 to Pin 3	Connect the VCC and V_{IN} pin	
	Open		X
J14	Pin 1 to Pin 2	Configures light load switching operation to be FPWM	X
	Pin 2 to Pin 3	Configures light load switching operation to be diode emulation	
	Open	Configures light load switching operation to be skip	
TP6		Positive input to the VAUX net	
TP7		Negative input to the VAUX net	
TP8		Positive input to the TRK pin of the LM5123-Q1	
TP9		Negative input to the TRK pin of the LM5123-Q1	

Table 2-4 indicates the dedicated voltage probe points of the EVM. These points are used to make measurements on the EVM.

Table 2-4. Probe Points

Sense Point	Name	Description
TP1	VIN+	Sense point for the positive input voltage
TP2	VOUT+	Sense point for the positive output voltage
TP3	SW	Sense point for the switch node of the boost controller
TP4	GND	Sense point for the negative output voltage
TP5	VIN-	Sense point for the negative input voltage
J3	PGND	Power ground connection
J6	PGND	Power ground connection
J8		Probe point for many of the LM5123 control signals
	1	BIAS
	2	PGOOD
	3	UVLO
	4	COMP
	5	SS
	6	AGND

2.3 EVM Configurations

Section 2.3 shows modifications outside of the default configuration that are used to further evaluate the LM5123-Q1.

2.3.1 Output Voltage Tracking

Section 2.3.1describes how to setup the evaluation module for dynamic output voltage tracking.

The LM5123EVM-BST is typically configured to have fixed output voltage of 24 V. Figure 2-2 shows the resistor divider connection from the REF pin to the TRK pin that sets the output voltage to 24 V. R_{VREFT} is R24 and R_{VREFB} is R26 referring to the schematic.

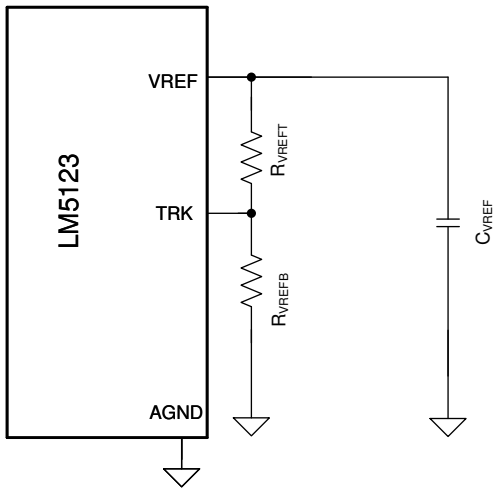

Figure 2-2. Fixed Output Voltage Configuration

To dynamically change the output voltage, R_{VREFT} and R_{VEFB} are removed and the TRK pin voltage is driven directly to change the output voltage. See the data sheet for selecting the voltage range of the LM5123-Q1 and setting the TRK pin voltage to produce the desired output voltage. Figure 2-3 shows the configuration to change the output voltage dynamically. R_{SET} is R25 in the schematic.

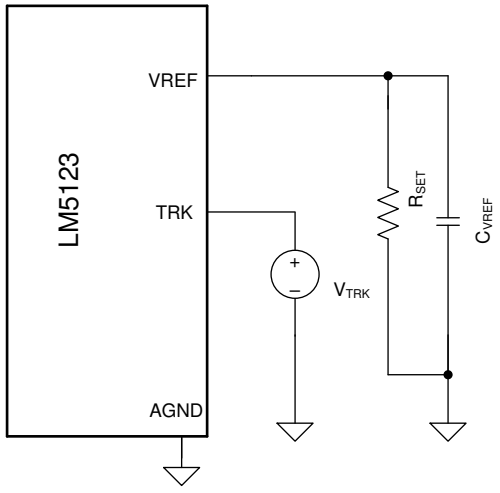

Figure 2-3. Variable Output Voltage Configuration

To recreate the waveforms in Section 4.7, R_{SET} is set to be 24.9 kΩ and the TRK pin is driven between 400 mV and 750 mV, setting the output voltage to 24 V and 45 V respectively.

3 Test Setup and Procedures

Figure 3-1 shows the required test setup to recreate the results found in Section 4.

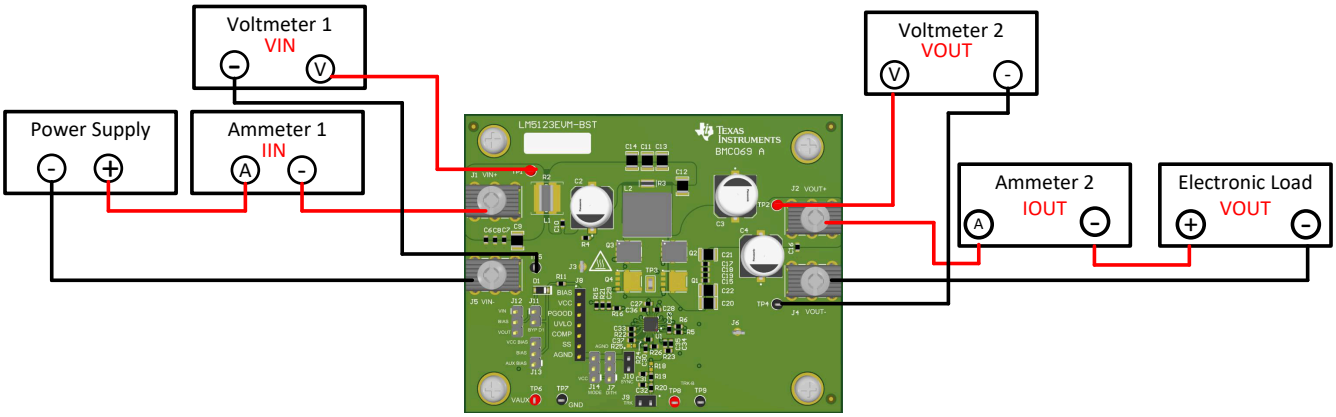

Figure 3-1. EVM Test Setup

3.1 Equipment

The following test equipment is needed to test the LM5123EVM-BST as shown in Figure 3-1.

- Power supply: The input voltage source (V_{IN}) should be a variable supply. The power supply should source 7 V to 36 V and be able to supply more than 15 A of current.
- Electronic Load: Load connected to the output of the evaluation module. The electronic load should be able to dissipate 100 W at 24 V.
- Multimeters: For DC measurements
  - Voltmeter 1 (V_{IN}): Capable of measuring the input voltage range up to 18 V
  - Voltmeter 2 (V_{OUT}): Capable of measuring output voltage of 24 V
  - Ammeter 1 (I_{IN}): Capable of 15-A DC measurement. A shunt resistor may also be used to measure the input current
  - Ammeter 2 (I_{OUT}): Capable of at least 5-A DC measurement
- Oscilloscope: minimum of 20-MHz bandwidth and 10x probes.

4 Test Results

Section 4 covers the test results of the evaluation module.

4.1 Efficiency

Figure 4-1 shows the efficiency of the evaluation module when configured in FPWM switching mode.

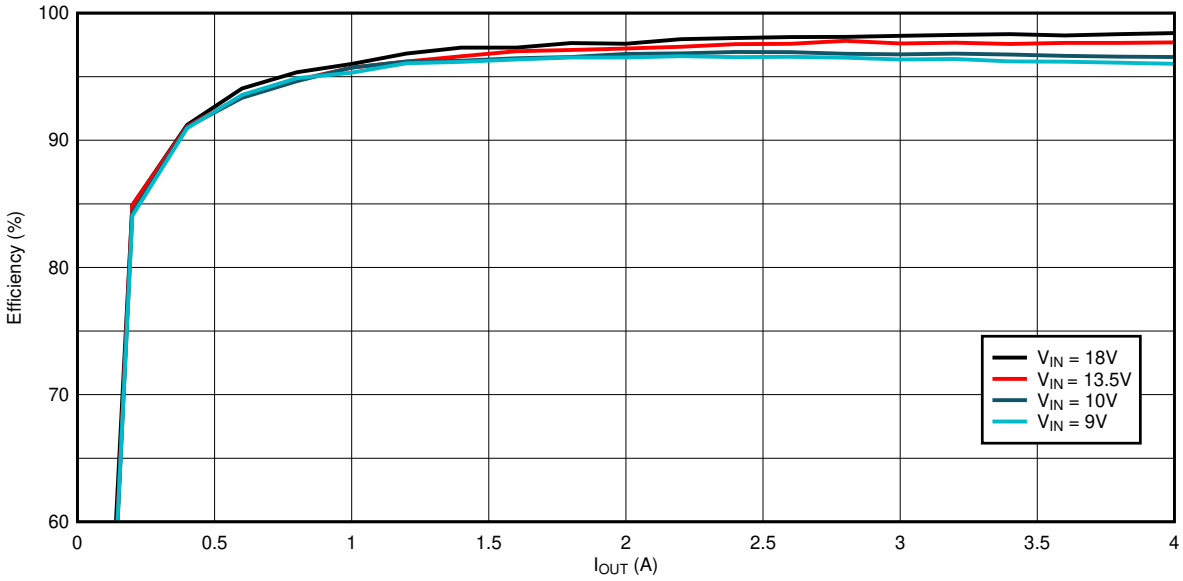

Figure 4-1. Efficiency: V_{OUT} = 24 V

Figure 4-2 shows the efficiency comparison between Skip switching mode and FPWM switching mode at light loading conditions.

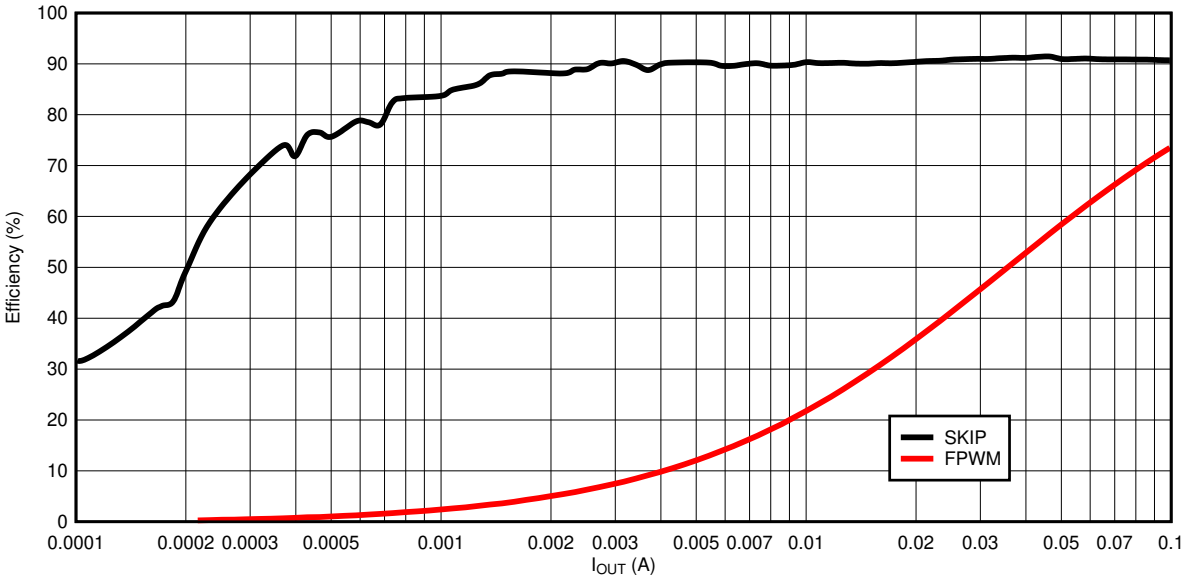

Figure 4-2. Efficiency: V_{OUT} = 24-V Light Load

4.2 Load Regulation

Figure 4-3 shows the load regulation for a 24-V output.

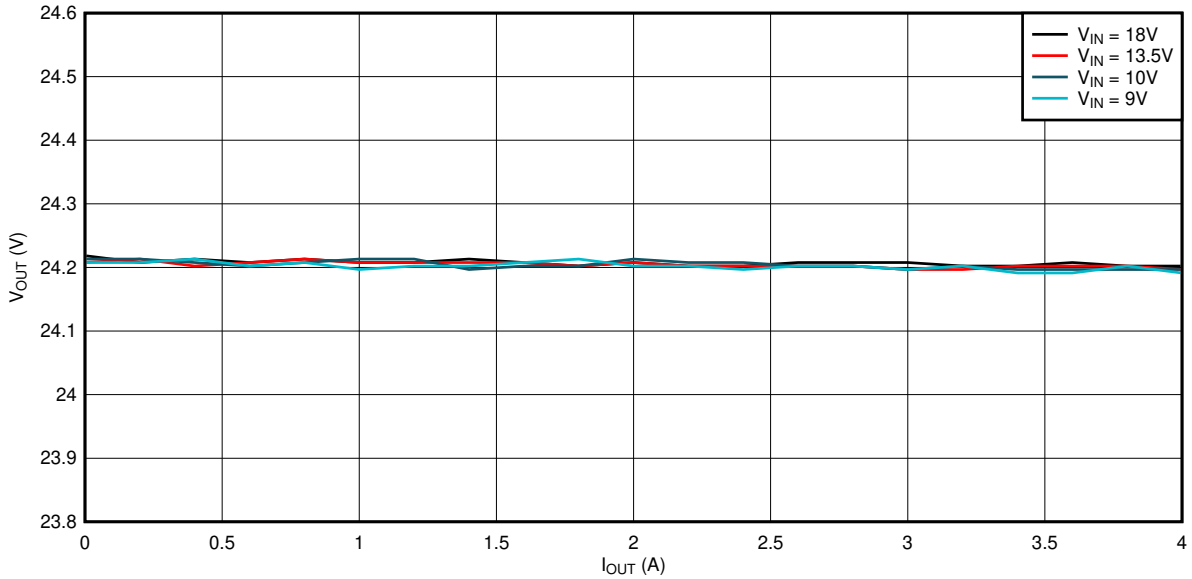

Figure 4-3. 24-V Load Regulation

4.3 Thermal Performance

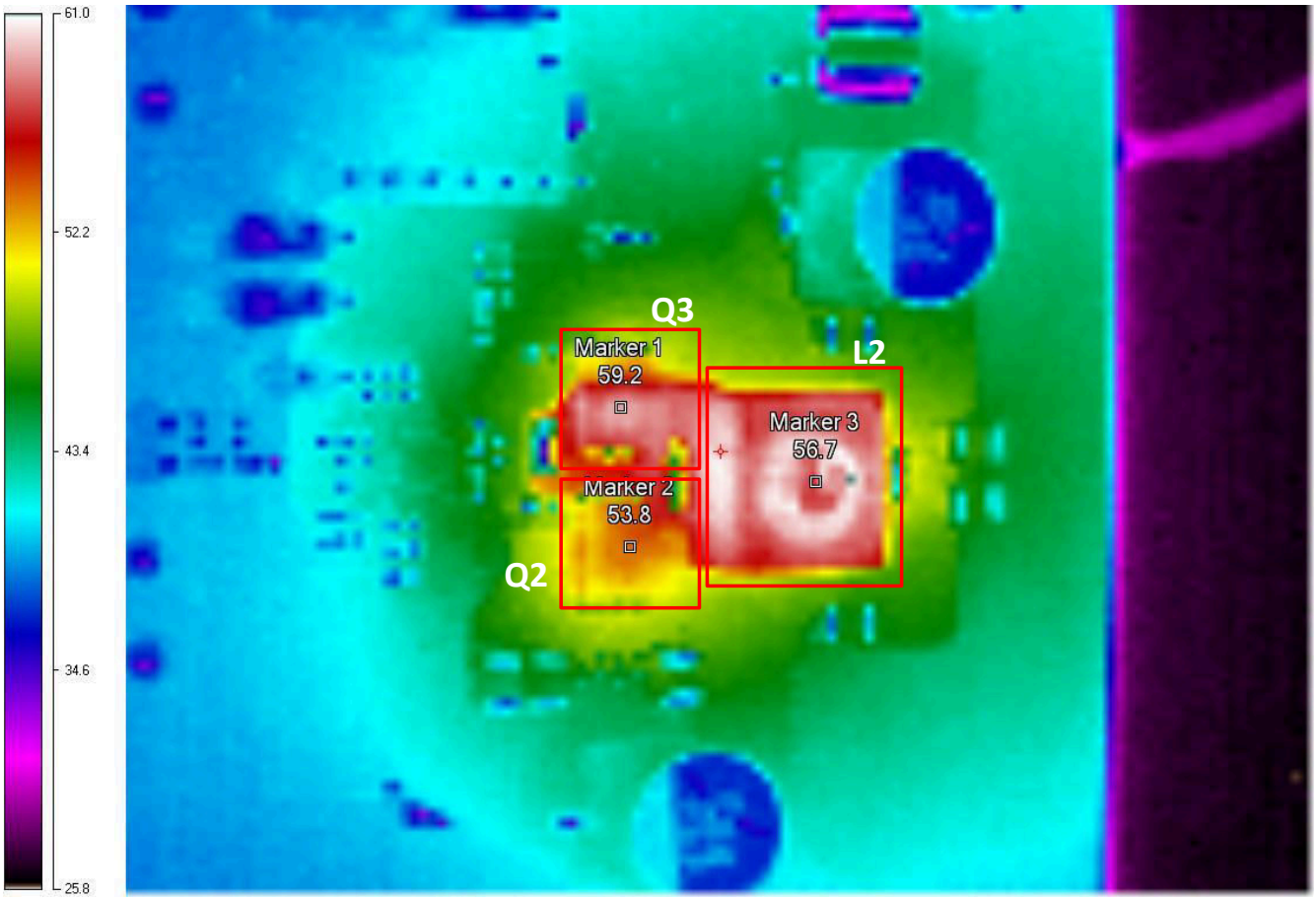

Figure 4-4. Thermal Performance: V_{IN} = 9 V, V_{OUT} = 24 V P_{OUT} = 100 W, No Forced Airflow

4.4 Start-up Waveforms

Figure 4-5 through Figure 4-8 show the start-up waveforms of the LM5123EVM-BST.

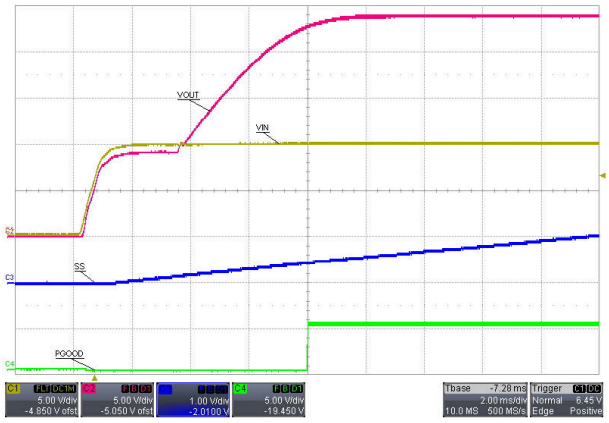

Figure 4-5. V_{IN} = 9 V, V_{OUT} = 24 V, P_{OUT} = 100 W

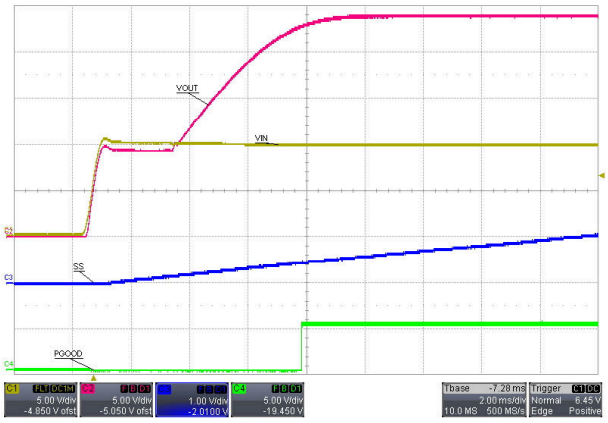

Figure 4-6. V_{IN} = 10 V, V_{OUT} = 24 V, P_{OUT} = 100 W

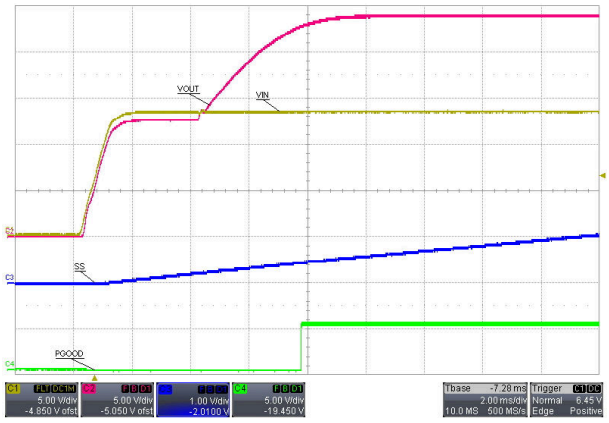

Figure 4-7. V_{IN} = 13.5 V, V_{OUT} = 24 V, P_{OUT} = 100 W

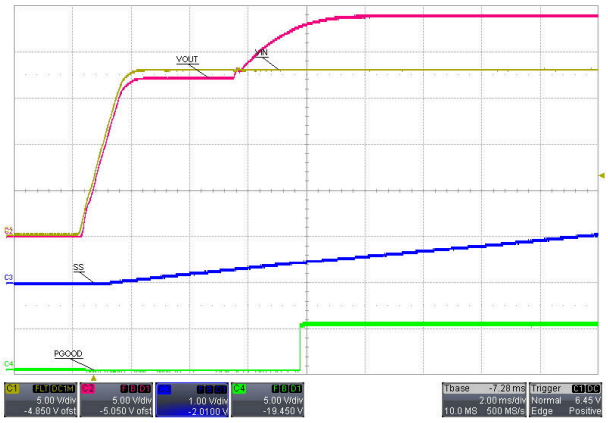

Figure 4-8. V_{IN} = 18 V, V_{OUT} = 24 V, P_{OUT} = 100 W

4.5 Steady State Operation

Full load operation

Figure 4-9 through Figure 4-12 show the steady state waveforms of the LM5123EVM-BST.

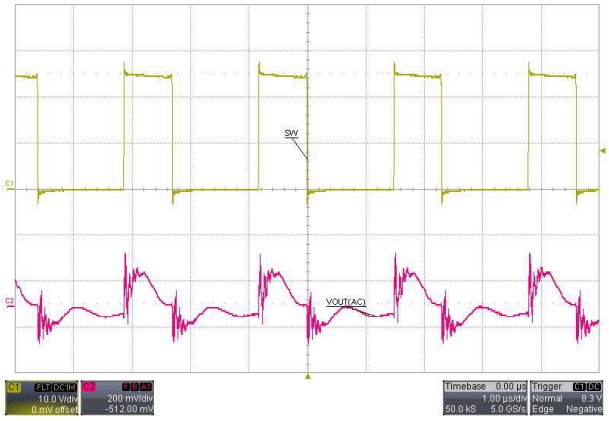

Figure 4-9. V_{IN} = 9 V, V_{OUT} = 24 V, P_{OUT} = 100 W

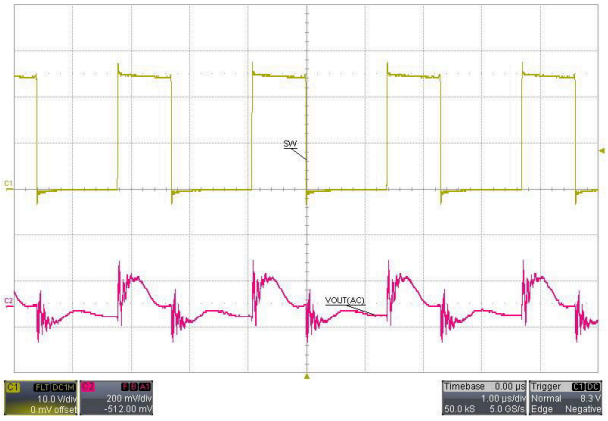

Figure 4-10. V_{IN} = 10 V, V_{OUT} = 24 V, P_{OUT} = 100 W

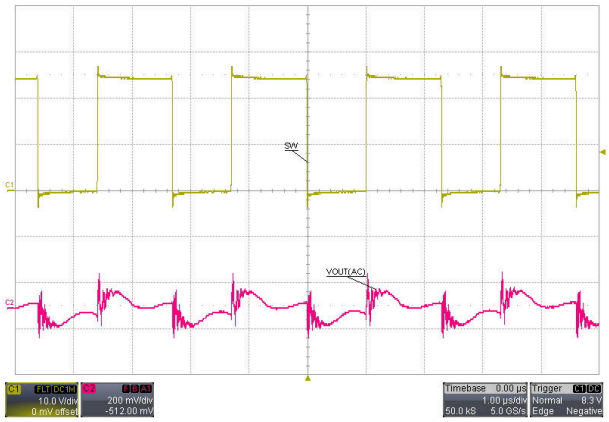

Figure 4-11. V_{IN} = 13.5 V, V_{OUT} = 24 V, P_{OUT} = 100 W

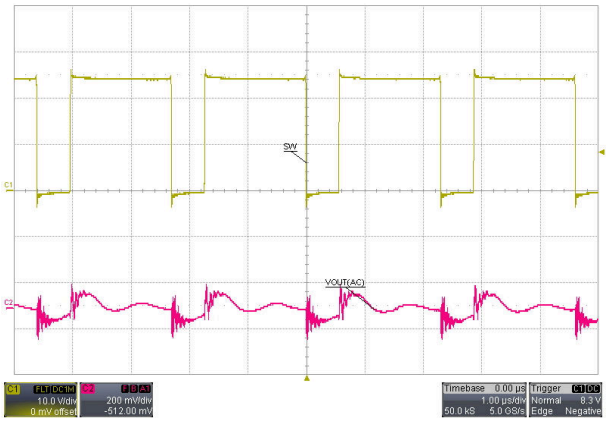

Figure 4-12. V_{IN} = 18 V, V_{OUT} = 24 V, P_{OUT} = 100 W

4.6 Load Transient Response

Figure 4-13 to Figure 4-16 show the load transient response of the evaluation module

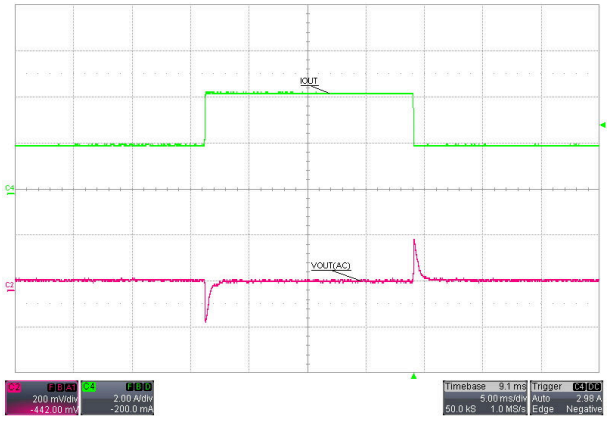

Figure 4-13. V_{IN} = 9 V, I_{OUT} = 2 A to 4 A

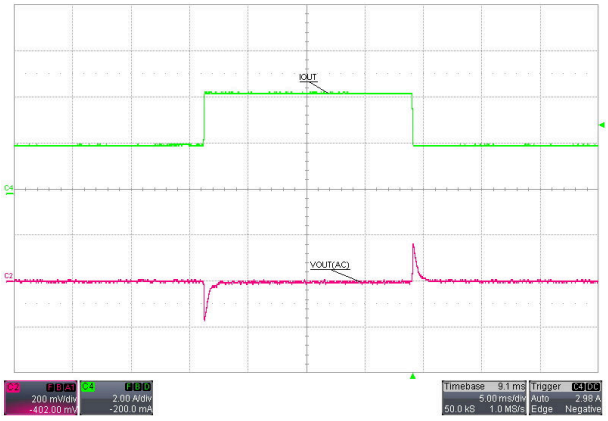

Figure 4-14. V_{IN} = 10 V, I_{OUT} = 2 A to 4 A

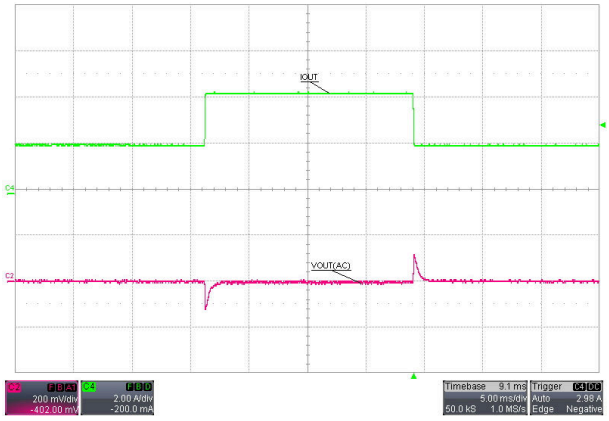

Figure 4-15. V_{IN} = 13.5 V, I_{OUT} = 2 A to 4 A

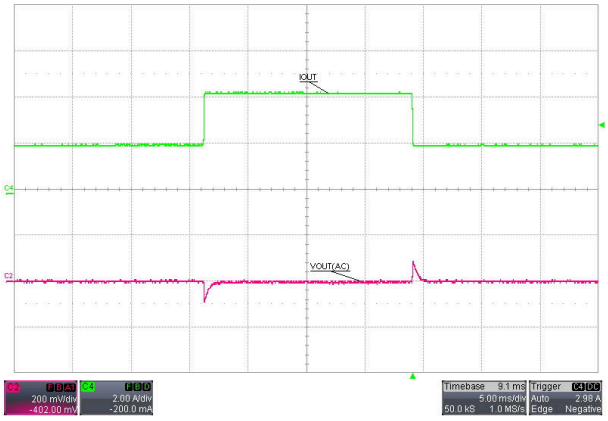

Figure 4-16. V_{IN} = 18 V, I_{OUT} = 2 A to 4 A

4.7 Output Voltage Tracking

Section 2.3.1 shows the output tracking using the TRK pin of the LM5123-Q1. To see more details on configuring the evaluation module to replicate these waveforms, see Section 2.3.1.

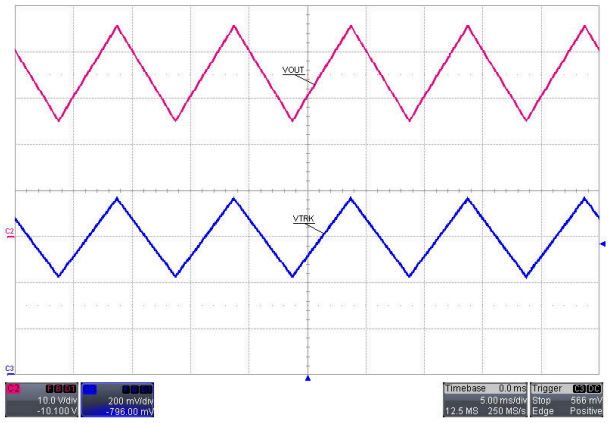

Figure 4-17. Triangle Voltage Tracking, V_{IN} = 13.5 V, P_{OUT} = 100 W, V_{OUT} 24 V to 45 V

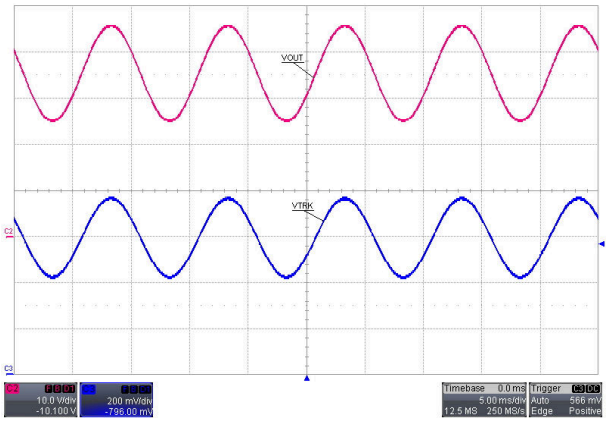

Figure 4-18. Sine Voltage Tracking, V_{IN} = 13.5 V, P_{OUT} = 100 W, V_{OUT} 24 V to 45 V

5 PCB Layers

Figure 5-1 through Figure 5-6 illustrate the EVM PCB layout.

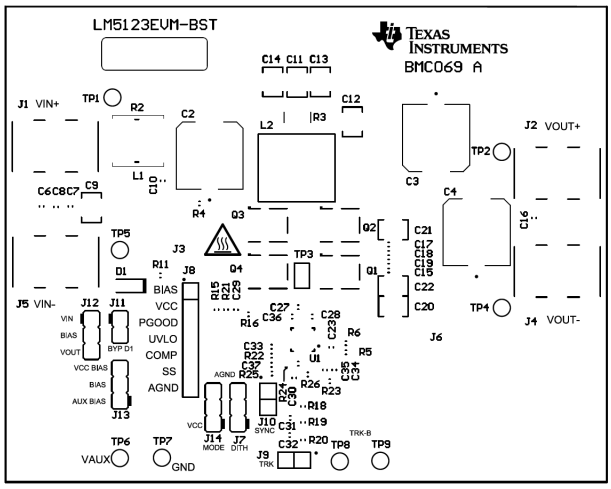

Figure 5-1. Layout: Top Silk Screen

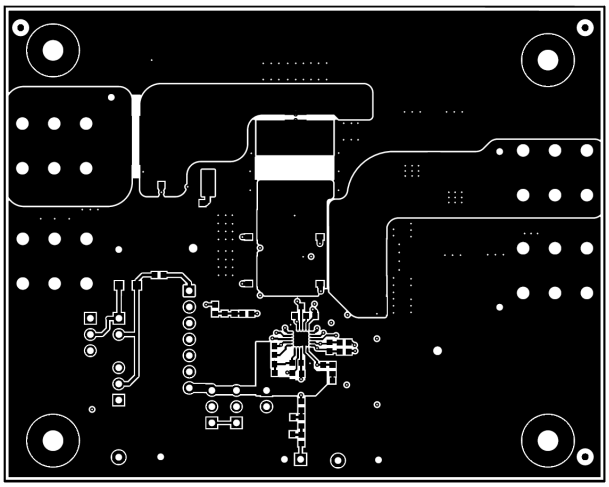

Figure 5-2. Layout: Top Layer

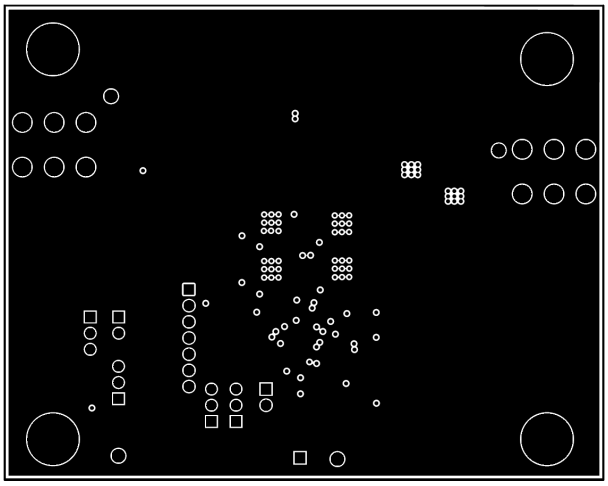

Figure 5-3. Layout: Signal Layer 1

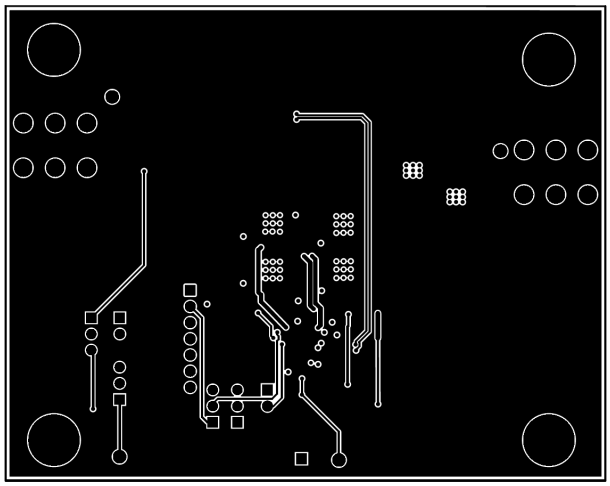

Figure 5-4. Layout: Signal Layer 2

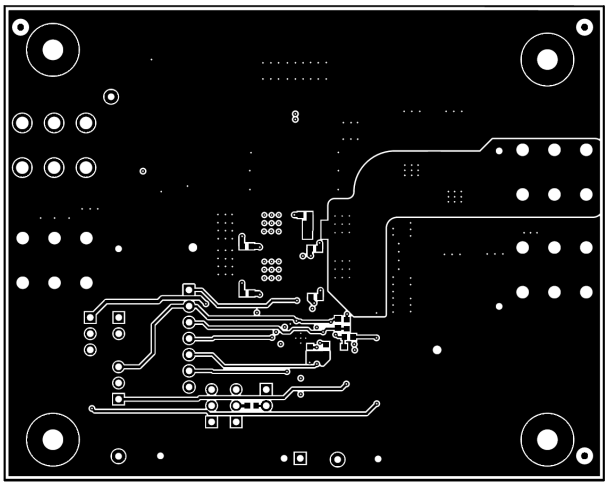

Figure 5-5. Layout: Bottom Layer

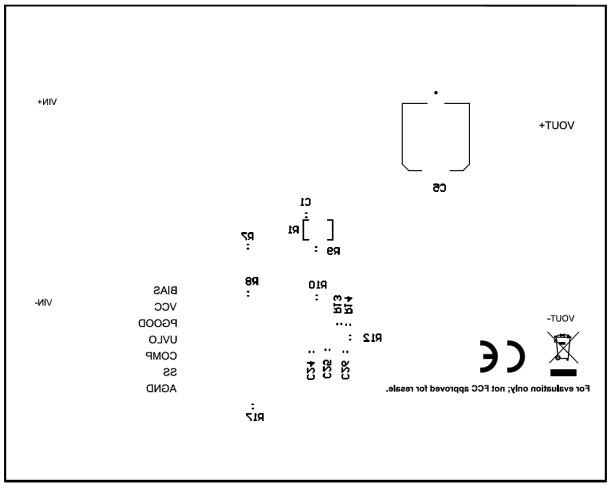

Figure 5-6. Layout: Bottom Silk Screen

6 Schematic

Figure 6-1 illustrates the EVM schematic.

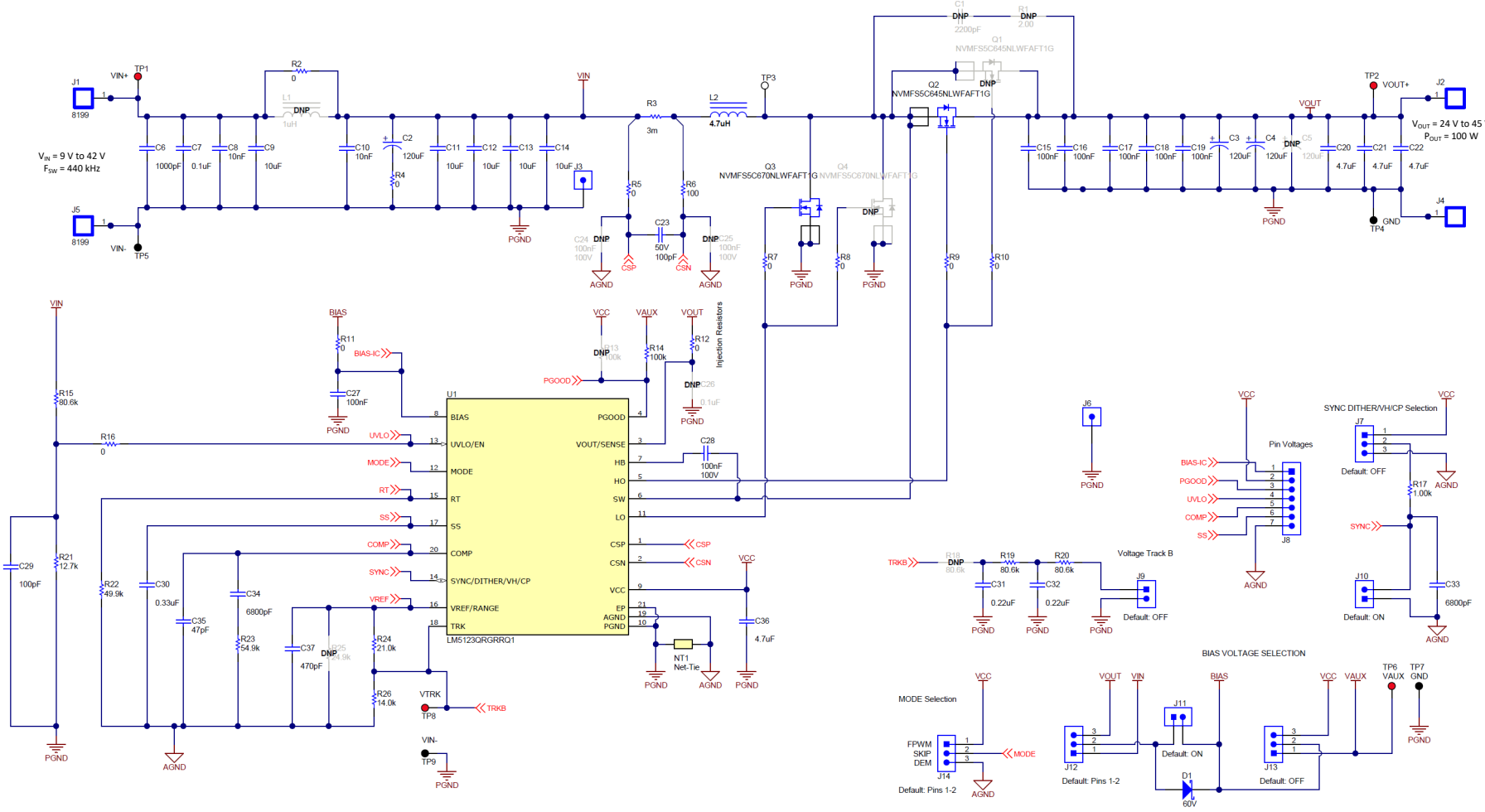

Figure 6-1. Schematic

7 Bill of Materials

Table 7-1 details the EVM bill of materials.

Table 7-1. Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
C2, C3, C4	3	120µF	CAP ALUM POLY HYB 120UF 50V SMD	RADIAL	EEH-ZC1H121P	Panasonic
C6	1	1000pF	CAP, CERM, 1000 pF, 50 V, ±±10%, X7R, 0603	0603	C0603X102K5RACTU	Kemet
C7	1	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±10%, X7R, 0603	0603	C1608X7R1H104K080AA	TDK
C8, C10	2	0.01uF	CAP, CERM, 0.01 µF, 100 V,±10%, X7R, 0603	0603	885012206114	Wurth Elektronik
C9, C11, C12, C13, C14	5	10uF	CAP, CERM, 10 uF, 50 V, ±10%, X7R, 1210	1210	GRM32ER71H106KA12L	MuRata
C15, C16, C17, C18, C19, C27, C28	7	0.1uF	CAP, CERM, 0.1 uF, 100 V,±10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCJ188R72A104KA01D	MuRata
C20, C21, C22	3	4.7uF	CAP, CERM, 4.7 uF, 100 V, ±10%, X7S, AEC-Q200 Grade 1, 1210	1210	CGA6M3X7S2A475K200AB	TDK
C23	1	100pF	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 0, 0603	0603	CGA3E2NP01H101J080AA	TDK
C29	1	100pF	CAP, CERM, 100 pF, 50 V,±1%, C0G/NP0, 0603	0603	C0603C101F5GACTU	Kemet
C30	1	0.33uF	CAP, CERM, 0.33 uF, 10 V, ±10%, X5R, 0603	0603	C0603C334K8PACTU	Kemet
C31, C32	2	0.22uF	CAP, CERM, 0.22 uF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7R1H224K080AB	TDK
C33, C34	2	6800pF	CAP, CERM, 6800 pF, 50 V,±5%, C0G/NP0, 0603	0603	GRM1885C1H682JA01D	MuRata
C35	1	47pF	CAP, CERM, 47 pF, 100 V,±5%, C0G/NP0, AEC-Q200 Grade 1, 0603	0603	C0603C470J1GACAUTO	Kemet
C36	1	4.7uF	CAP, CERM, 4.7 uF, 16 V, ±10%, X6S, 0603	0603	C1608X6S1C475K080AC	TDK
C37	1	470pF	CAP, CERM, 470 pF, 50 V, ±5%, C0G/NP0, 0603	0603	06035A471JAT2A	AVX
D1	1	60V	Diode, Schottky, 60 V, 1 A, SOD-123F	SOD-123F	PMEG6010CEH,115	Nexperia
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1, J2, J4, J5	4		TERMINAL SCREW PC 30AMP, TH	12.9x6.3x7.9 mm	8199	Keystone
J3, J6	2		TEST POINT SLOTTED .118", TH	Test point, TH Slot Test point	1040	Keystone
J7, J12, J13, J14	4		Header, 2.54 mm, 3x1, Gold, TH	Header, 2.54 mm, 3x1, TH	GBC03SAAN	Sullins Connector Solutions
J8	1		Header, 100mil, 7x1, Gold, TH	7x1 Header	TSW-107-07-G-S	Samtec
J9, J10	2		Header, 100mil, 2x1, Tin, TH	Header 2x1	90120-0122	Molex
J11	1		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54 mm, 2x1, TH	GBC02SAAN	Sullins Connector Solutions
L2	1	4.7uH	Inductor, Shielded, Composite, 4.7 uH, 24 A, 0.01 ohm, SMD	Inductor, 11.3x10x10mm	XAL1010-472MEB	Coilcraft
LBL1	1			PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q2	1	60V	MOSFET, N-CH, 60 V, 100 A, AEC-Q101, SO-8FL	SO-8FL	NVMFS5C645NLWFAFT1G	ON Semiconductor

Table 7-1. Bill of Materials (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
Q3	1	60V	MOSFET, N-CH, 60 V, 17 A, AEC-Q101, SO-8FL	SO-8FL	NVMFS5C670NLWFAFT1G	ON Semiconductor
R2	1	0	RES, 0, 5%, 2 W, 2512 WIDE	2512 WIDE	RCL12250000Z0EG	Vishay Draloric
R3	1	3m	3 ±1% 1W Chip Resistor Wide 1206 (3216 Metric), 0612 Anti-Sulfur, Automotive AEC-Q200, Current Sense, Moisture Resistant, Pulse Withstanding Metal Element	1206	WSL06123L000FEA	Vishay
R4, R5, R7, R8, R9, R10, R11, R16	8	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3GEY0R00V	Panasonic
R6	1	100	RES, 100, 1%, 0.1 W, 0603	0603	RC0603FR-07100RL	Yageo
R12	1	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL	Yageo
R14	1	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R15, R19, R20	3	80.6k	RES, 80.6 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060380K6FKEA	Vishay-Dale
R17	1	1.00k	RES, 1.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R21	1	12.7k	RES, 12.7 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060312K7FKEA	Vishay-Dale
R22	1	49.9k	RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3EKF4992V	Panasonic
R23	1	54.9k	RES, 54.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060354K9FKEA	Vishay-Dale
R24	1	21.0k	RES, 21.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060321K0FKEA	Vishay-Dale
R26	1	14.0k	RES, 14.0 k, 0.5%, 0.1 W, 0603	0603	RT0603DRE0714KL	Yageo America
SH-J1, SH-J2, SH-J3, SH-J4	4		Single Operation 2.54mm Pitch Open Top Jumper Socket	Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
TP1, TP2, TP6, TP8	4		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone
TP3	1		Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone
TP4, TP5, TP7, TP9	4		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
U1	1		2.2-MHz Wide VIN Low-IQ Synchronous Boost Controller with Tracking	VQFN20	LM5123QRGRRQ1	Texas Instruments

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1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

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

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

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE 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。
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 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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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.

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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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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.

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