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 200-W, from an input voltage of 8-V to 18-V and switching at 440 kHz. The output voltage can be dynamically up to 33-V using the TRK pin of the LM5123-Q1.

This EVM is designed for ease of configuration, enabling an 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

All trademarks are the property of their respective owners.

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 8-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 200-W. The output voltage can be to 33-V while using the TRK pin of the LM5123-Q1. The EVM can be used to evaluate the LM5123-Q1 for many applications. Figure 1-1 shows the standard application circuit for the LM5123EVM-BST evaluation module.

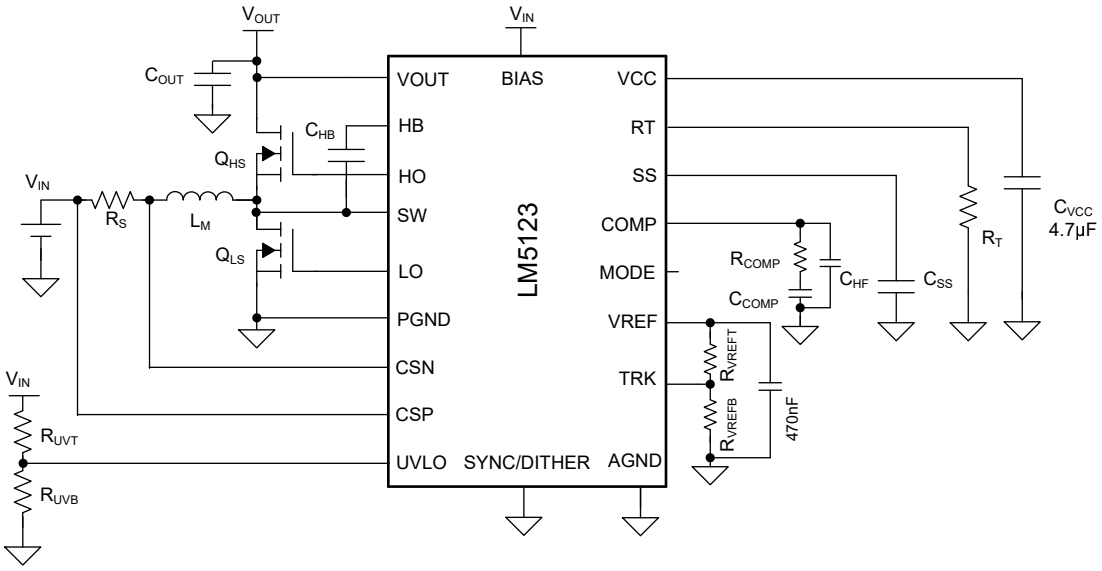

Figure 1-1. Typical Application Circuit

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 8-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} = 14-V, V_{OUT} = 24-V, P_{OUT} = 200-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.

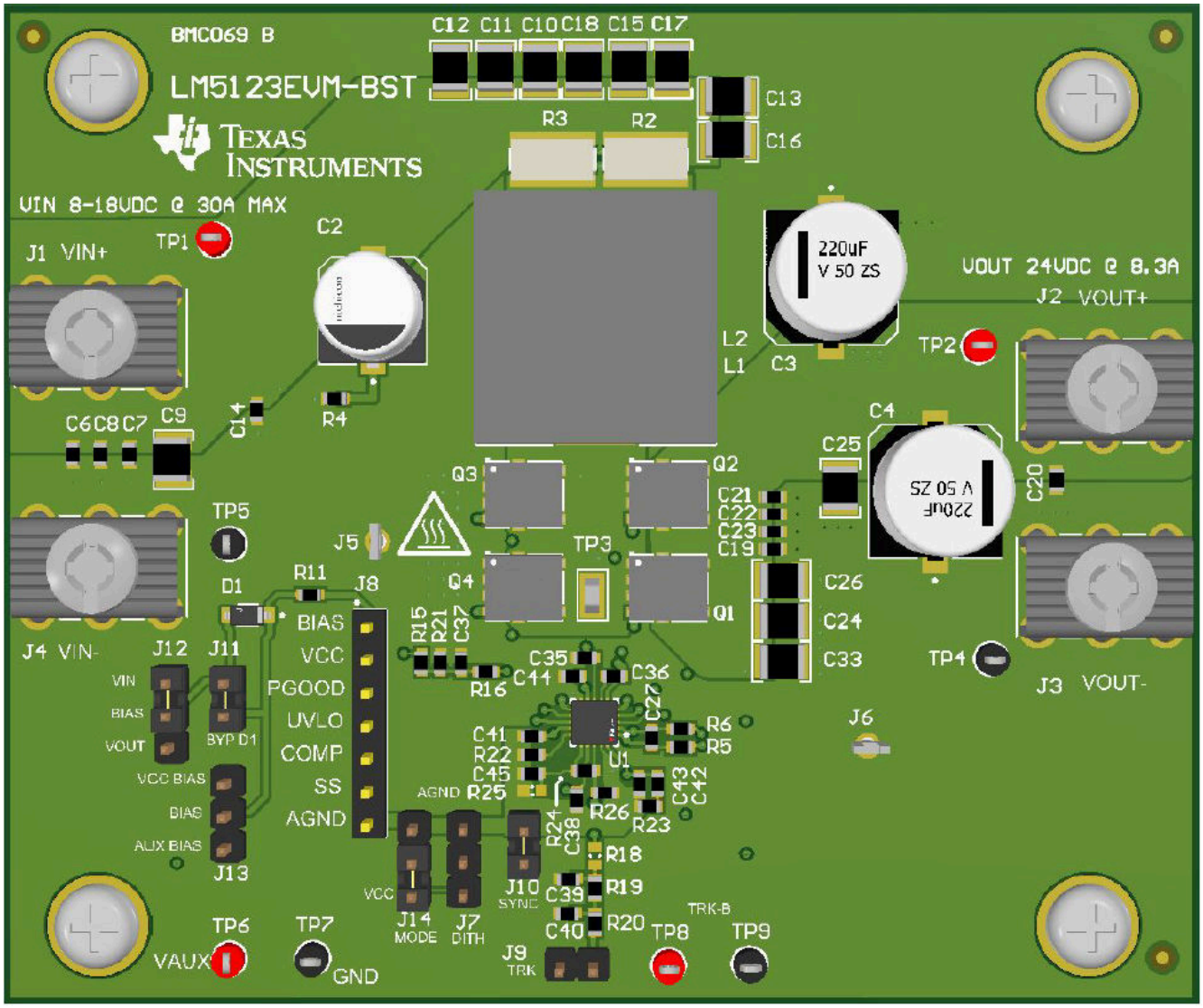

Figure 2-1. EVM Photo

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		8	14	36	V
	UVLO voltage levels	Turn-off		6		V
		Turn-on		7		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} = 550 mV			33		V
Output Power					200	W
SYSTEM CHARACTERISITCS						
Switching Frequency				440		kHz
Full Load Efficiency	V_{IN} = 14V, 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.

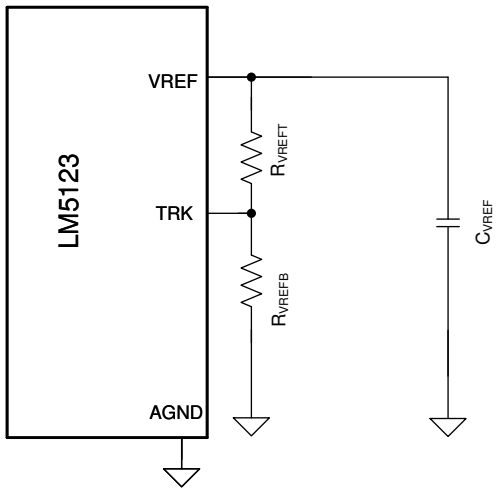

Figure 2-2. Fixed Output Voltage Configuration

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.

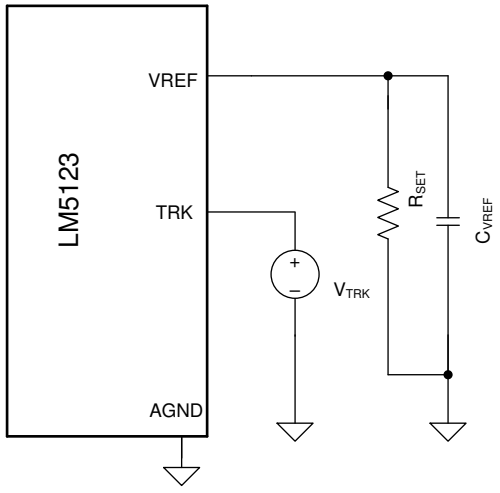

Figure 2-3. Variable Output Voltage Configuration

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 550 mV, setting the output voltage to 24 V and 33V respectively.

3 Test Setup and Procedures

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

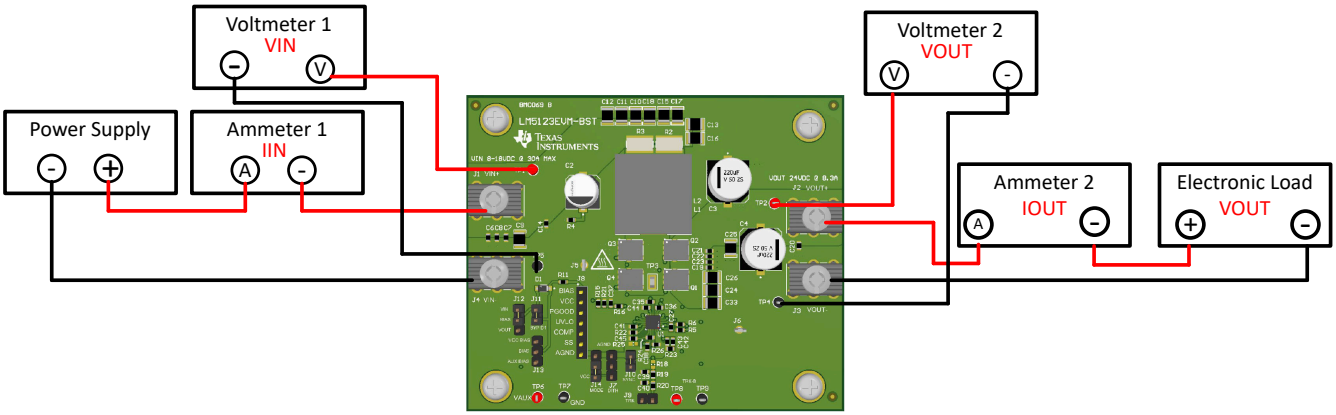

Figure 3-1. EVM Test Setup

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 30-A of current.
- Electronic Load: Load connected to the output of the evaluation module. The electronic load should be able to dissipate 200-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 30-A DC measurement. A shunt resistor may also be used to measure the input current
  - Ammeter 2 (I_{OUT}): Capable of at least 10-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.

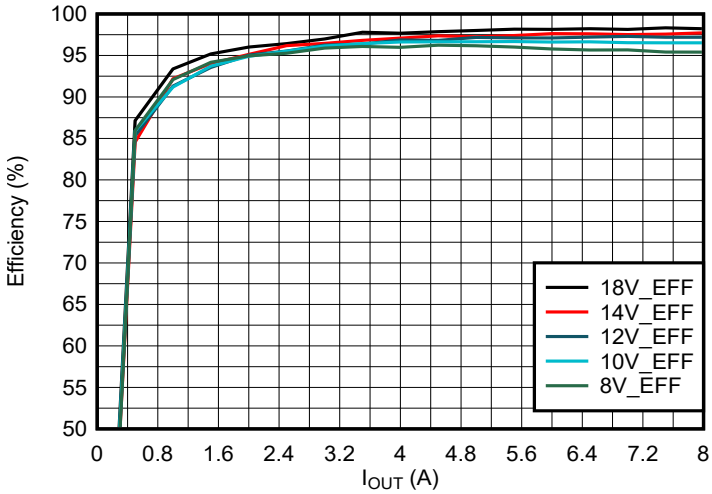

Figure 4-1. Efficiency: V_{OUT} = 24-V

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

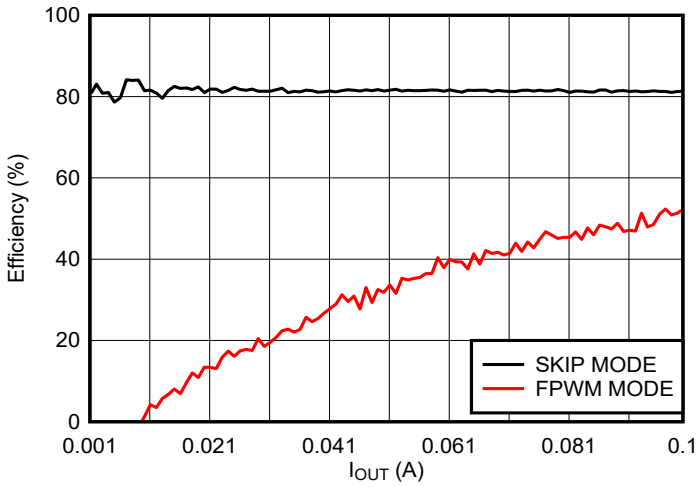

Figure 4-2. Efficiency: V_{OUT} = 24-V Light Load

4.2 Load Regulation

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

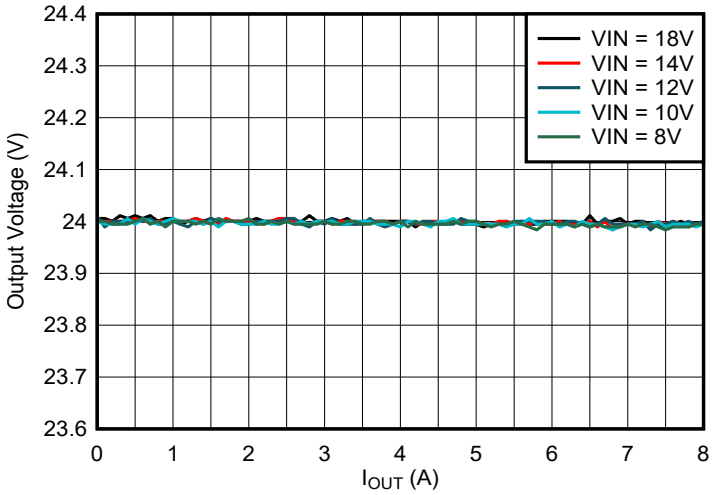

Figure 4-3. 24-V Load Regulation

4.3 Thermal Performance

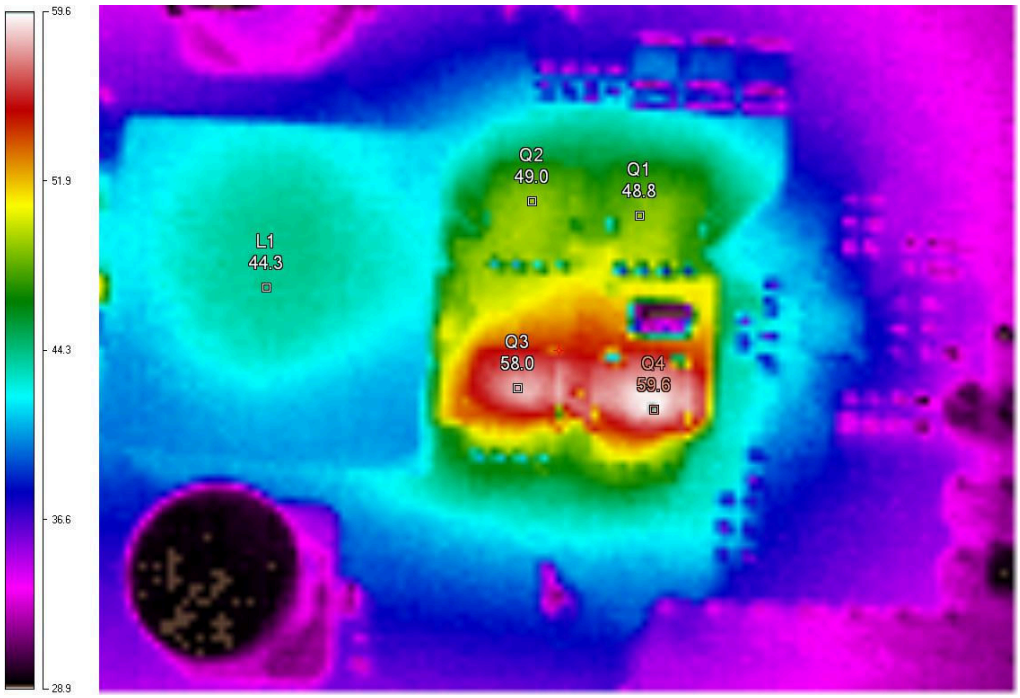

Figure 4-4. Thermal Performance: V_{IN} = 8-V, V_{OUT} = 24-V P_{OUT} = 200-W, No Forced Airflow

4.4 Start-up Waveforms

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

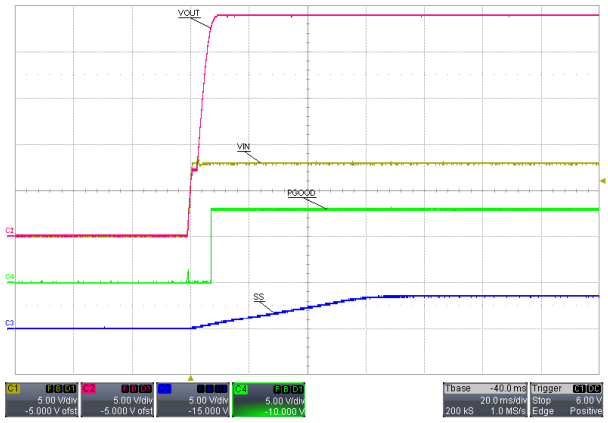

Figure 4-5. V_{IN} = 8-V, V_{OUT} = 24-V, P_{OUT} = 200-W

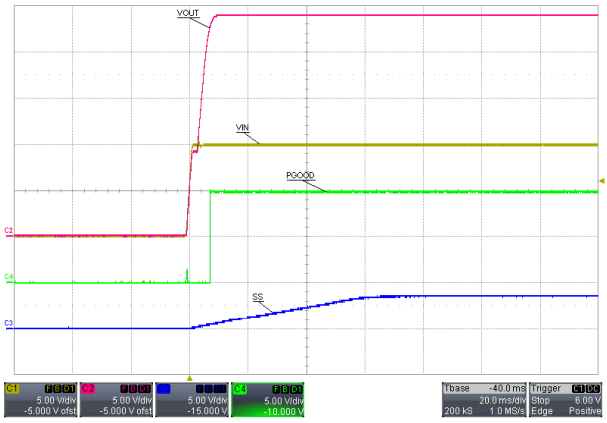

Figure 4-6. V_{IN} = 10-V, V_{OUT} = 24-V, P_{OUT} = 200-W

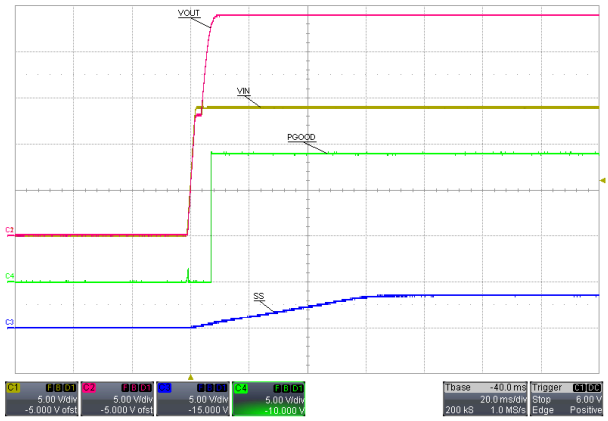

Figure 4-7. V_{IN} = 14-V, V_{OUT} = 24-V, P_{OUT} = 200-W

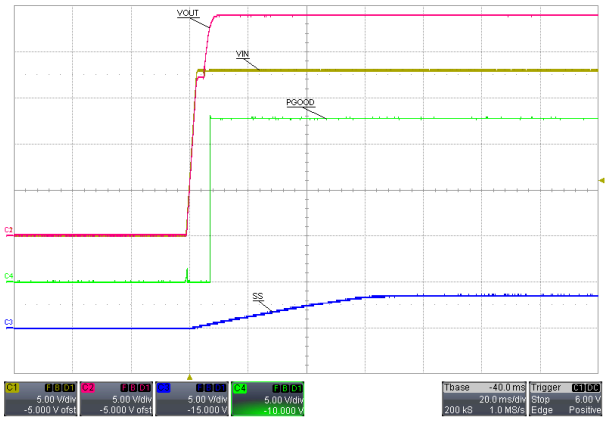

Figure 4-8. V_{IN} = 18-V, V_{OUT} = 24-V, P_{OUT} = 200-W

4.5 Steady State Operation

Full load operation

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

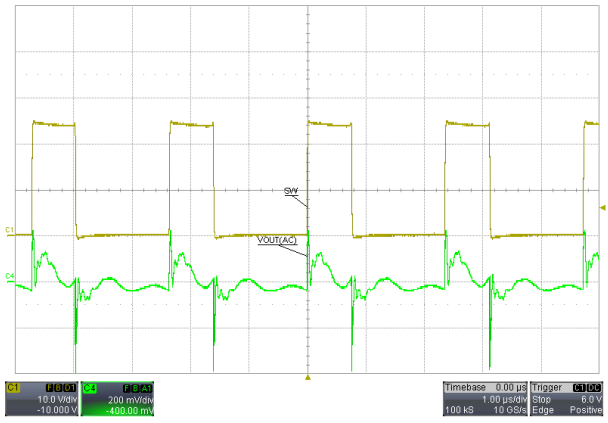

Figure 4-9. V_{IN} = 8-V, V_{OUT} = 24-V, P_{OUT} = 200-W

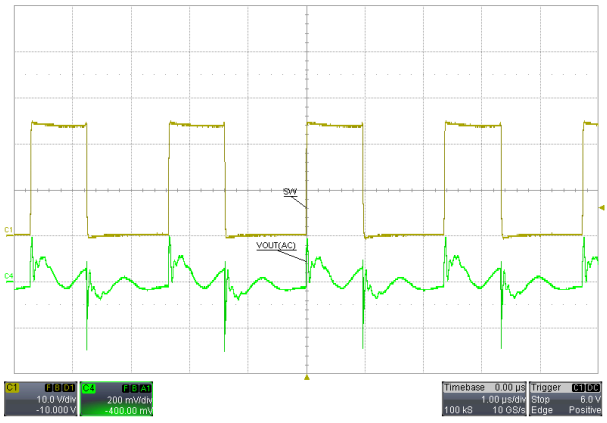

Figure 4-10. V_{IN} = 10-V, V_{OUT} = 24-V, P_{OUT} = 200-W

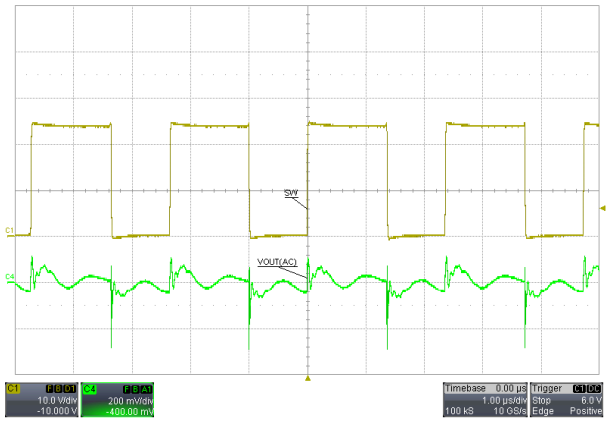

Figure 4-11. V_{IN} = 14-V, V_{OUT} = 24-V, P_{OUT} = 200-W

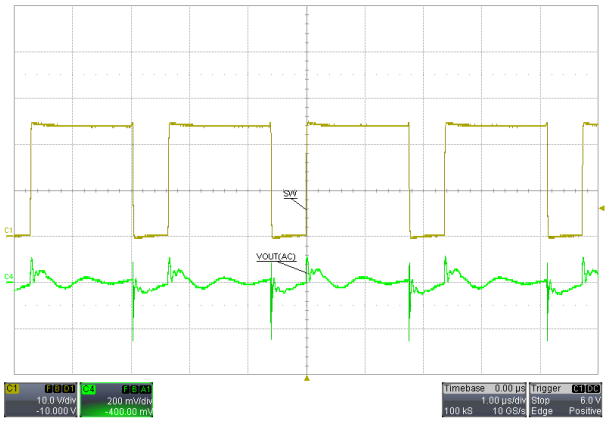

Figure 4-12. V_{IN} = 18-V, V_{OUT} = 24-V, P_{OUT} = 200-W

4.6 Load Transient Response

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

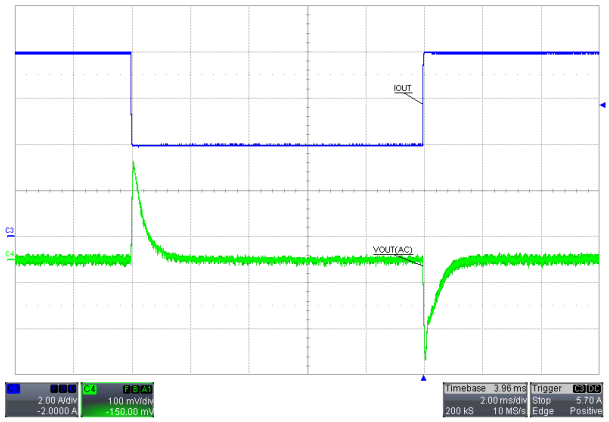

Figure 4-13. V_{IN} = 8-V, I_{OUT} = 4-A to 8-A

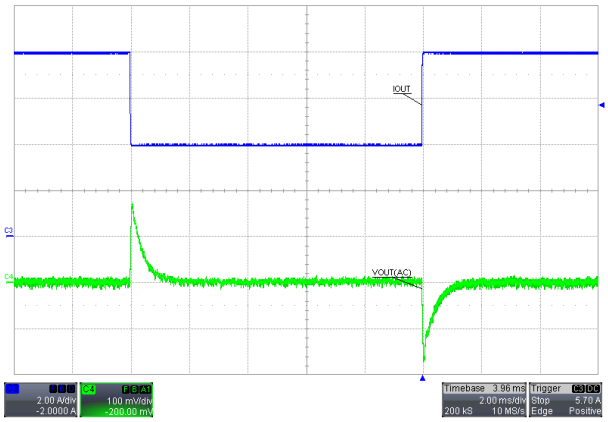

Figure 4-14. V_{IN} = 10-V, I_{OUT} = 4-A to 8-A

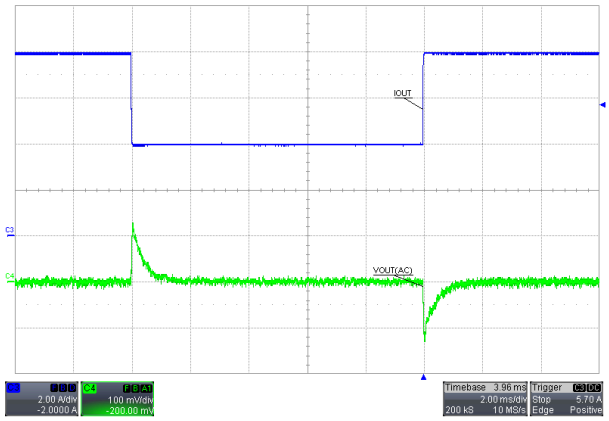

Figure 4-15. V_{IN} = 14-V, I_{OUT} = 4-A to 8-A

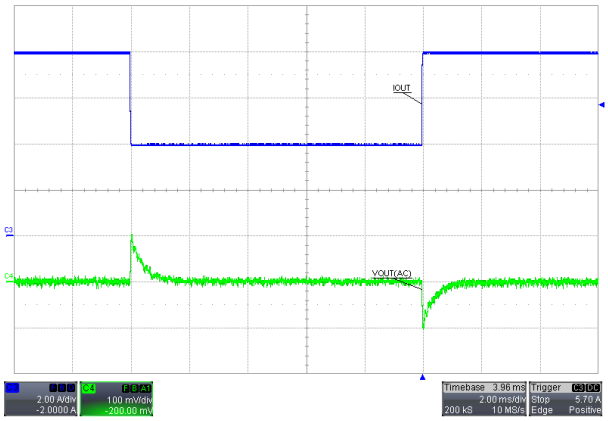

Figure 4-16. V_{IN} = 18-V, I_{OUT} = 4-A to 8-A

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.

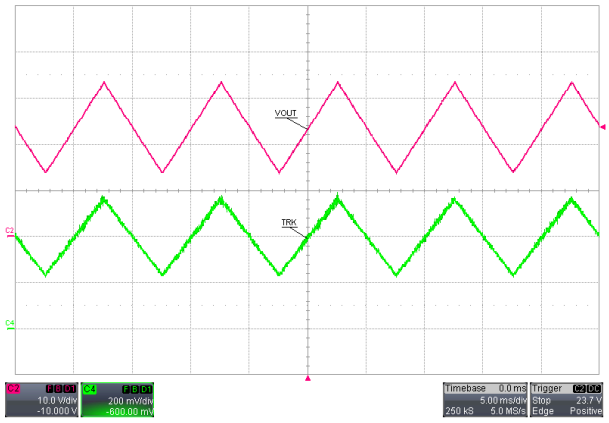

Figure 4-17. Triangle Voltage Tracking, V_{IN} = 14-V, P_{OUT} = 200-W, V_{OUT} 14-V to 33-V

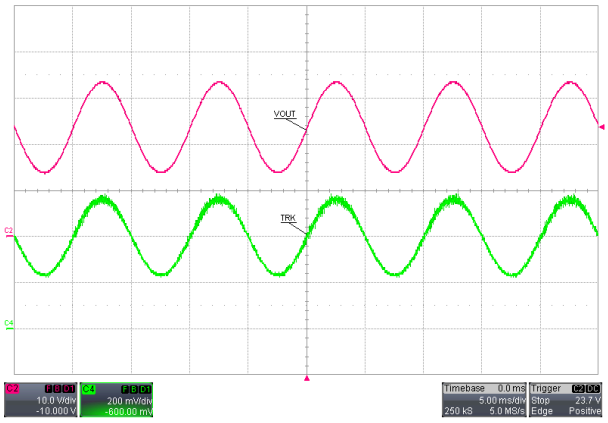

Figure 4-18. Sine Voltage Tracking, V_{IN} = 14-V, P_{OUT} = 200-W, V_{OUT} 14-V to 33-V

5 PCB Layers

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

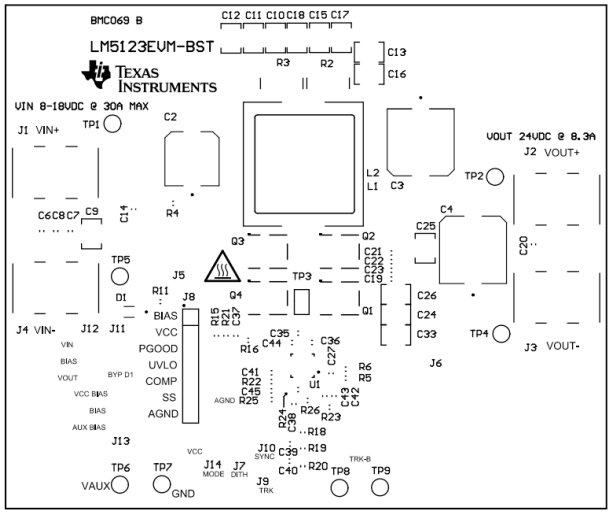

Figure 5-1. Layout: Top Silk Screen

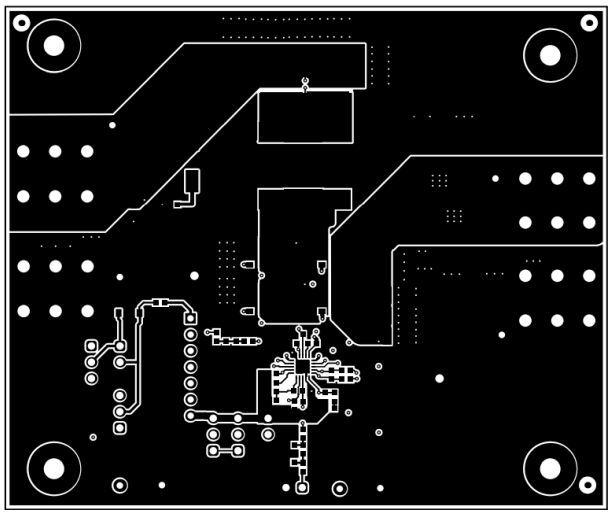

Figure 5-2. Layout: Top Layer

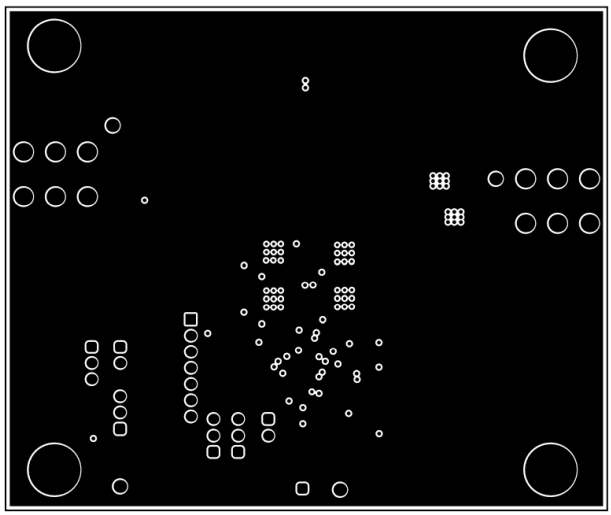

Figure 5-3. Layout: Signal Layer 1

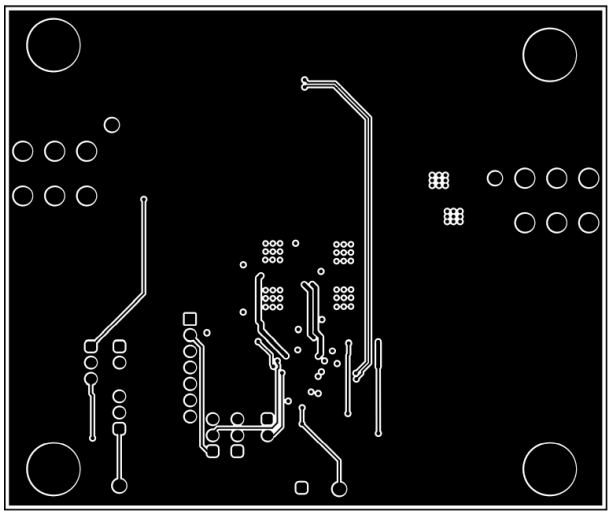

Figure 5-4. Layout: Signal Layer 2

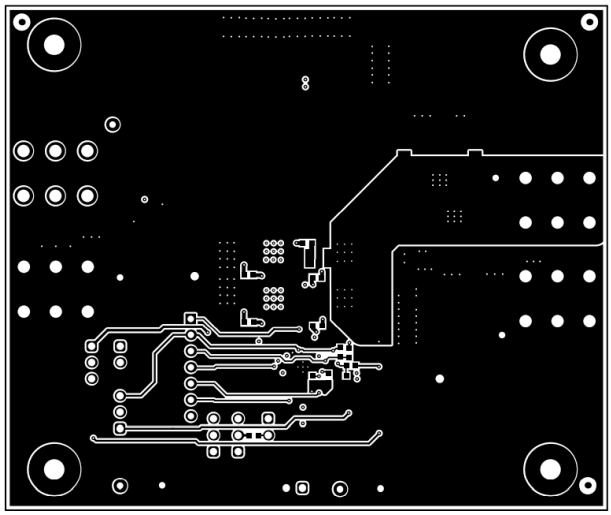

Figure 5-5. Layout: Bottom Layer

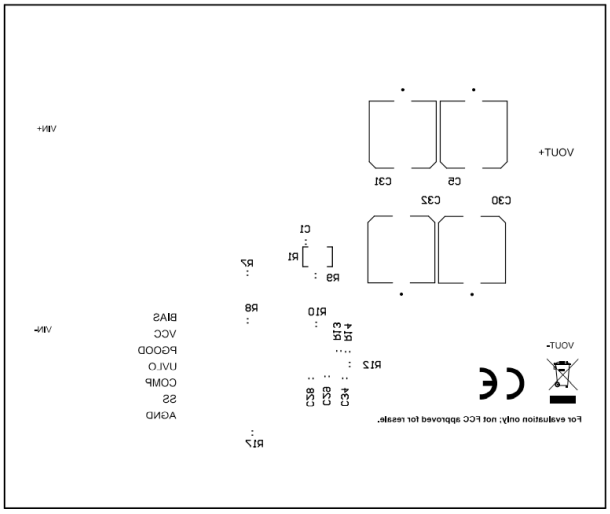

Figure 5-6. Layout: Bottom Silk Screen

6 Schematic

Figure 6-1 illustrates the EVM schematic.

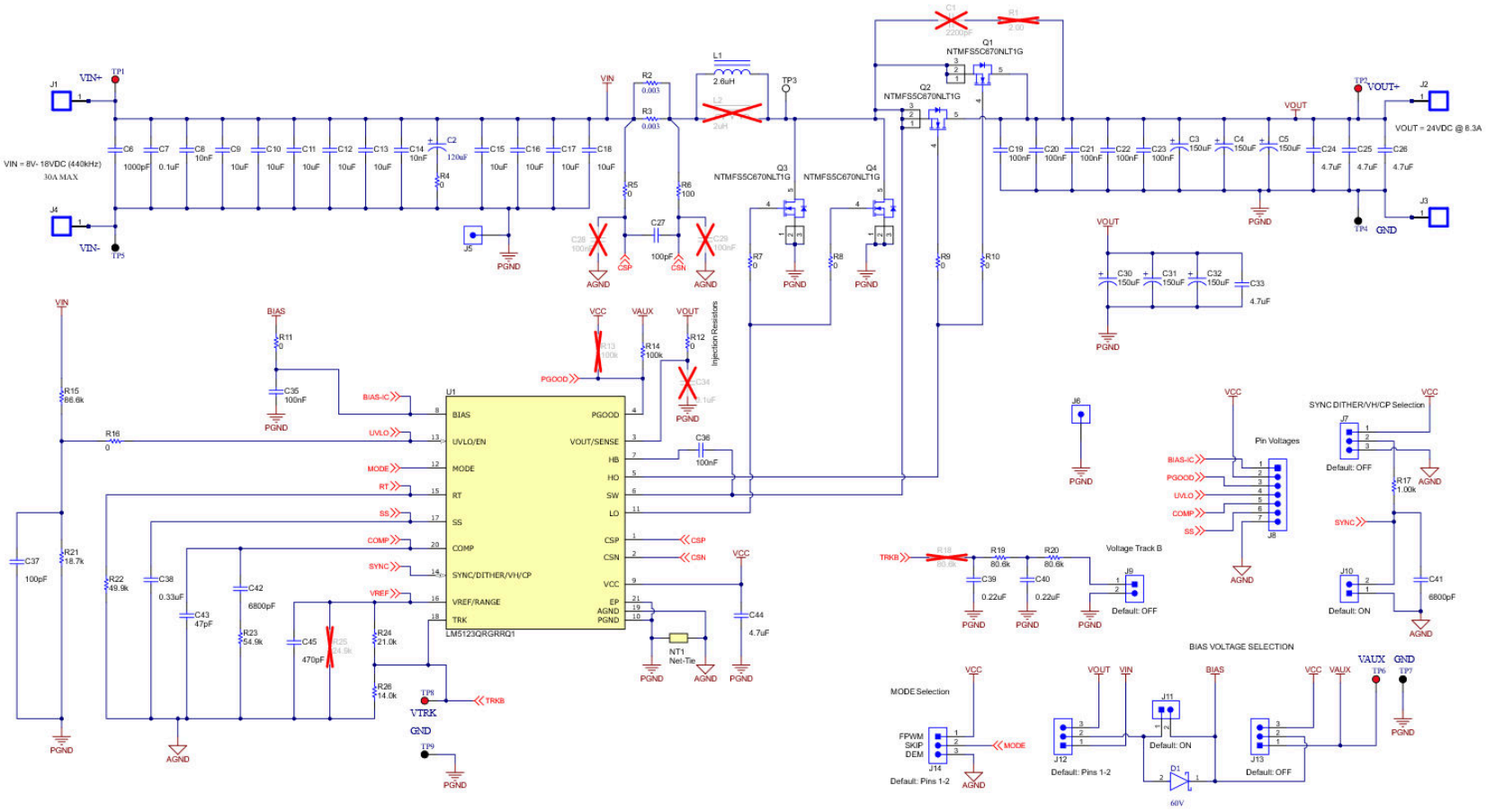

Figure 6-1. Schematic

7 Bill of Materials

Table 7-1 details the EVM bill of materials.

Table 7-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C2	1	120µF	Cap Aluminum Polymer 120uF 50VDC 20% (8 X 12mm) SMD 0.025 Ohm 2100mA 4000h 135C Automotive T/R	RADIAL	PCH1H121MCL2GS	Nichicon
C3, C4, C5, C30, C31, C32	6	150µF	150µF 50V Aluminum - Polymer Capacitors 17mOhm 4000 hrs @ 125°C	RADIAL	EEH-ZS1H151P	Panasonic
C6	1	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0603	603	C0603X102K5RACTU	Kemet
C7	1	0.1uF	CAP, CERM, 0.1 uF, 50 V, ±10%, X7R, 0603	0603	C1608X7R1H104K080AA	TDK
C8, C14	2	0.01uF	CAP, CERM, 0.01 µF, 100 V,+/- 10%, X7R, 0603	603	8.85012E+11	Wurth Elektronik
C9, C10, C11, C12, C13, C15, C16, C17, C18	9	10uF	CAP, CERM, 10 uF, 50 V, +/- 10%, X7R, 1210	1210	GRM32ER71H106KA12L	MuRata
C19, C20, C21, C22, C23, C35, C36	7	0.1uF	CAP, CERM, 0.1 uF, 100 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	603	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
C24, C25, C26, C33	4	4.7uF	CAP, CERM, 4.7 uF, 100 V, +/- 10%, X7S, AEC-Q200 Grade 1, 1210	1210	CGA6M3X7S2A475K200AB	TDK
C27	1	100pF	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, AEC-Q200 Grade 0, 0603	603	CGA3E2NP01H101J080AA	TDK
C37	1	100pF	CAP, CERM, 100 pF, 50 V,+/- 1%, C0G/NP0, 0603	603	C0603C101F5GACTU	Kemet
C38	1	0.33uF	CAP, CERM, 0.33 uF, 10 V, +/- 10%, X5R, 0603	603	C0603C334K8PACTU	Kemet
C39, C40	2	0.22uF	CAP, CERM, 0.22 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	603	CGA3E3X7R1H224K080AB	TDK
C41, C42	2	6800pF	CAP, CERM, 6800 pF, 50 V,+/- 5%, C0G/NP0, 0603	603	GRM1885C1H682JA01D	MuRata

Table 7-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
C43	1	47pF	CAP, CERM, 47 pF, 100 V,+/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	603	C0603C470J1GACAUTO	Kemet
C44	1	4.7uF	CAP, CERM, 4.7 uF, 16 V, +/- 10%, X6S, 0603	603	C1608X6S1C475K080AC	TDK
C45	1	470pF	CAP, CERM, 470 pF, 50 V, +/- 5%, C0G/NP0, 0603	603	06035A471JAT2A	AVX
D1	1		Diode Schottky 60 V 1A Surface Mount SOD-123	SOD-123	PMEG6010CEGWX	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		Hex Standoff Threaded #4-40 Nylon 0.750" (19.05mm) 3/4" Natural	HEX_STANDOFF	1902D_Ndrill	Keystone Electronics
J1, J2, J3, J4	4		TERMINAL SCREW PC 30AMP, TH	12.9x6.3x7.9 mm	8199	Keystone
J5, 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, 2.54mm, 3x1, TH	61300311121	Wurth Elektronik
J8	1		Header, 100mil, 7x1, Gold, TH	7x1 Header	TSW-107-07-G-S	Samtec
J9, J10, J11	3		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
L1	1	2.6uH	Inductor, Shielded Drum Core, WE-Superflux200, 2.6 uH, 31.5 A, 0.0016 ohm, SMD	18.3x8.9x18.2mm	7443556260	Wurth Elektronik
Q1, Q2, Q3, Q4	4	60V	MOSFET, N-CH, 60 V, 71 A, SO-8FL	SO-8FL	NTMFS5C670NLT1G	ON Semiconductor
R2, R3	2	0.003	RES, 0.003, 1%, 3 W, AEC-Q200 Grade 0, 2512 WIDE	2512 WIDE	KRL6432E-M-R003-F-T1	Susumu Co Ltd
R4, R5, R7, R8, R9, R10, R11, R16	7	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	603	ERJ-3GEY0R00V	Panasonic
R6	1	100	RES, 100, 1%, 0.1 W, 0603	603	RC0603FR-07100RL	Yageo
R12	1	0	RES, 0, 5%, 0.1 W, 0603	603	RC0603JR-070RL	Yageo
R14	1	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW0603100KFKEA	Vishay-Dale
R15	1	86.6k	RES, 86.6 k, 1%, 0.1 W, 0603	603	RC0603FR-0786K6L	Yageo
R17	1	1.00k	RES, 1.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW06031K00FKEA	Vishay-Dale

Table 7-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R19, R20	2	80.6k	RES, 80.6 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW060380K6FKEA	Vishay-Dale
R21	1	18.7k	RES, 18.7 k, 1%, 0.1 W, 0603	603	RC0603FR-0718K7L	Yageo
R22	1	49.9k	RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	ERJ-3EKF4992V	Panasonic
R23	1	54.9k	RES, 54.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW060354K9FKEA	Vishay-Dale
R24	1	21.0k	RES, 21.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW060321K0FKEA	Vishay-Dale
R26	1	14.0k	RES, 14.0 k, 0.5%, 0.1 W, 0603	603	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
C1	0	2200pF	CAP, CERM, 2200 pF, 100 V, +/- 10%, X7R, 0603	603	GRM188R72A222KA01D	MuRata
C28, C29	0	0.1uF	CAP, CERM, 0.1 uF, 100 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	603	GCJ188R72A104KA01D	MuRata
C34	0	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0603	603	C1608X7R1H104K080AA	TDK
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
L2	0	2uH	Inductor, Shielded, Composite, 2 uH, 39.9 A, 0.001909 ohm, SMD	15.2x8x16.2mm	XAL1580-202MEB	Coilcraft
R1	0	2	RES, 2.00, 1%, 0.5 W, AEC-Q200 Grade 0, 1210	1210	ERJ-14BQF2R0U	Panasonic
R13	0	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW0603100KFKEA	Vishay-Dale

Table 7-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
R18	0	80.6k	RES, 80.6 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW060380K6FKEA	Vishay-Dale
R25	0	24.9k	RES, 24.9 k, 0.1%, 0.1 W, 0603	603	RT0603BRD0724K9L	Yageo America

8 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (December 2020) to Revision A (December 2021)	Page
• Updated text to match the proper rating of the EVM	3
• Updated images throughout the user's guide	3

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

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