User's Guide

LM5177 Buck-Boost Controller Evaluation Module

ABSTRACT

The LM5177EVM-HP demonstrates a flexible high power buck-boost design using the LM5177 wide-V_{IN} buck-boost controller. The evaluation module is configured to operate from input voltage range of 4.2V to 36V and produce a regulated 16V output with up to 9.4A load current.

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Trademarks

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1 Features

Table 1-1. Board Specifications

Parameter	Value
Input voltage	4.2 V to 36 V
Output voltage	16 V
Maximum output current	9.4 A
Default switching frequency	400 kHz
Board size (four layers)	5.6 inch × 3.2 inch

- Smooth buck-boost operation
- Ultra high (> 97%) peak power conversion efficiency
- Adjustable output voltage using feedback resistor divider selection
- Programmable switching frequency with optional synchronization (SYNC)
- Cycle-by-cycle overcurrent protection
- Optional hiccup mode overload protection
- Programmable input undervoltage lockout (UVLO) threshold and hysteresis
- Output constant voltage (CV) and constant current (CC) options
- Optional frequency dithering for reduced EMI
- Setting of configuration resistor R_{CFG} through DIP switches

2 Connector, Test Point, and Selection Switch Descriptions

This section provides the I/O connectors, jumpers, and test points of the EVM.

The power supply must be connected to input connectors J1 and J3.

The load must be connected to output connectors J2 and J4.

2.1 Connector Descriptions

Table 2-1. Connectors

Reference Designator	Description
J1	Input voltage positive connection
J2	Output voltage connection and ISNSN test point
J3	Input voltage return connection
J4	Output voltage return connection
J5	Input voltage positive and input voltage return test point
J6	Output voltage positive and output voltage return test point
J7	External VIN/BIAS input connection
J8	R_FB input connection
J9	CFG external input connection
J10	FLT external input connection
J11	RT external input connection
J12	IMONOUT output connection
J13	I2C / USB2ANY connector (Not used for the LM5177)

2.2 Jumper Descriptions

Table 2-2. Jumpers

Reference Designator	Pins	Description	Default Connection
JP1	Pin 1 to Pin 2 (GND)	Jumper in position GND and power save mode (PSM) is enabled.	
	Pin 2 to Pin 3 (VCC)	Jumper in position VCC and power save mode (PSM) is disabled.	*
JP2	Pin 2 to Pin 3 (VCC)	Jumper in position VCC (SYNC pin tied VCC) and frequency synchronization is disabled.	*
	Open	Jumper removed and external clock feed in on the SYNC pin. SYNC is enabled.	
JP3	Pin 1 to Pin 2 (GND)	Jumper in position GND (DTRK pin tied GND) and digital voltage tracking is disabled.	*
	Open	Jumper removed and voltage feed in on the DTRK pin. DTRK is enabled in case the voltage on the DTRK pin is higher than the rising threshold of the VT(DTRK).	
JP4	Pin 1 to Pin 2 (VEXT)	Jumper in position VEXT and the input from J7-VEXT is connected to the BIAS pin.	
	Pin 3 to Pin 4 (VIN)	Jumper in position VIN. VIN (J1) is connected to the BIAS pin.	*
	Pin 5to Pin 6 (VOUT)	Jumper in position VOUT. VOUT (J2) is connected to the BIAS pin.	

Table 2-2. Jumpers (continued)

Reference Designator	Pins	Description	Default Connection
JP5	Pin 1 to Pin 2 (GND)	Jumper in position GND (EN/UVLO pin tied GND). The LM5177 is disabled.	
	Open	Jumper removed (the EN pin is tied to a resistor divider network consisting of R14 and R15). The EN/UVLO threshold is set with the resistor divider network.	*
	Pin 2to Pin 3 (VIN)	Jumper in position VCC (EN/UVLO pin tied VCC). The LM5177 is enabled.	

2.3 Test Point Descriptions

Table 2-3. Test Points

Reference Designator	Description
TP1 (VIN)	Input voltage positive test point
TP2 (VOUT)	Output voltage positive test point
TP3 (GND)	Input voltage return test point
TP4 (GND)	Output voltage return test point
TP5	CSA test point
TP6	CSB test point
TP7	SW2 test point
TP8	ISNSP test point
TP9 (BIAS)	BIAS voltage test point
TP10	VCC test point
TP11	SYNC test point

2.4 Selection Switch Descriptions

2.4.1 S1 and S2 CFG setting

These switches enable to set the resistor for the CFG pin. Details can be found in the *LM5177 Wide V_{IN} 4 Switch Buck Boost Controller Core IP* data sheet.

Table 2-4. CFG Pin Configuration Overview

#	DRSS	SCP – Hiccup Mode	PSM Entry Threshold	Current Limit
1	DISABLED	DISABLED	10%	DISABLED
2	ENABLED			
3	DISABLED	ENABLED		
4	ENABLED			
5	DISABLED	DISABLED	10%	ENABLED
6	ENABLED			
7	DISABLED	ENABLED		
8	ENABLED			
9	DISABLED	DISABLED	15%	DISABLED
10	ENABLED			
11	DISABLED	ENABLED		
12	ENABLED			
13	DISABLED	DISABLED	15%	ENABLED
14	ENABLED			
15	DISABLED	ENABLED		
16	ENABLED			

Note

Just one dip switch within S1 and S2 must be closed to avoid incorrect configuration settings.

3 Test Setup and Procedure

3.1 Test Setup

Figure 3-1 shows a typical test setup to evaluate the LM5177EVM-HP.

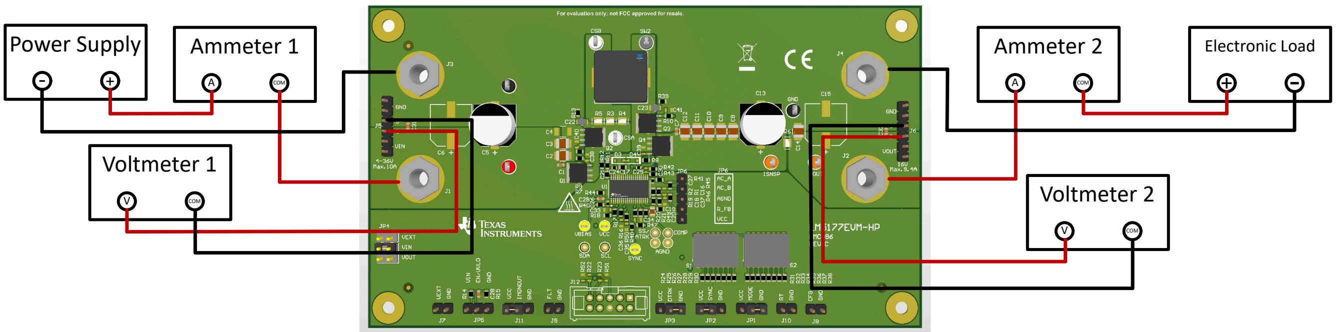

Figure 3-1. Typical EVM Connection Diagram

3.2 Test Procedure

1. Set the power supply current limit to 10 A. Turn off the power supply. Connect the positive output of the power supply to J1 and the negative output to J3.
2. Connect the load to J2 for the positive connection and J4 for the negative connection.
3. Set the power supply voltage to 16 V and the electronic load to 0.1 A. The electronic load voltage must be in regulation with a nominal 16-V output.
4. Slowly increase the load while monitoring the output voltage between J6-VCC and J6-GND. The output voltage must remain in regulation with a nominal 16-V output as the load is increased up to 9.4 A.
5. Slowly sweep the input voltage from 16 V to 36 V. The output voltage must remain in regulation with a nominal 16-V output.
6. Decrease the load to 2.5 A.
7. Slowly sweep the input voltage from 36 V to 5 V. The output voltage must remain in regulation with a nominal 16-V output.
8. Decrease the input voltage down to 0 V to shut down the buck-boost converter, and then turn off the load.

3.3 Precautions

CAUTION

Prolonged operation with low input at full power causes heating of the FETs (Q1 to Q4). Board surface is hot. Do not touch. Contact can cause burns.

4 Test Data and Performance Curves

4.1 Thermal Performance

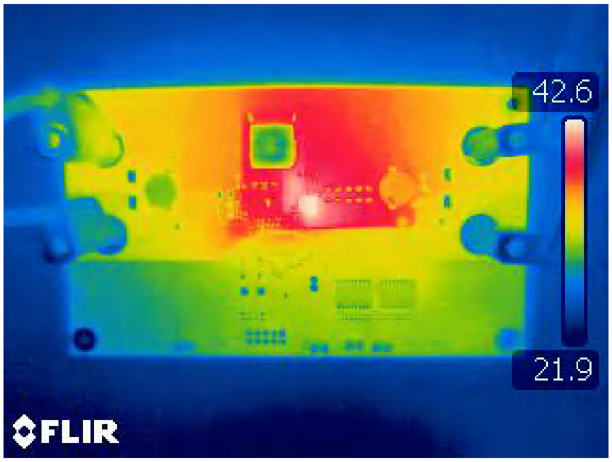

Figure 4-1. Thermal Image: V_{IN} = 4.2 V, I_{OUT} = 2.2 A, No Forced Air Cooling

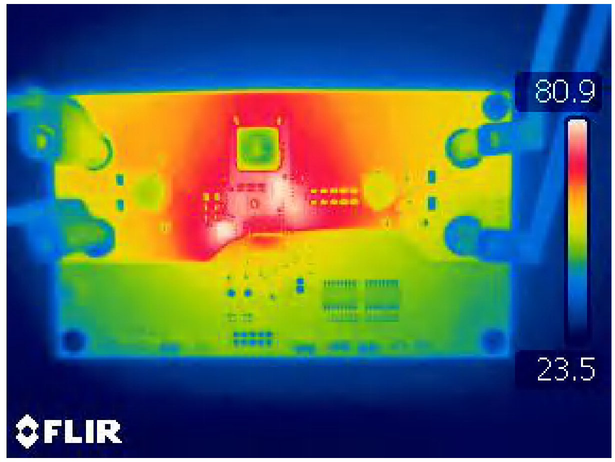

Figure 4-2. Thermal Image: V_{IN} = 16 V, I_{OUT} = 9.4 A, No Forced Air Cooling

4.2 Efficiency

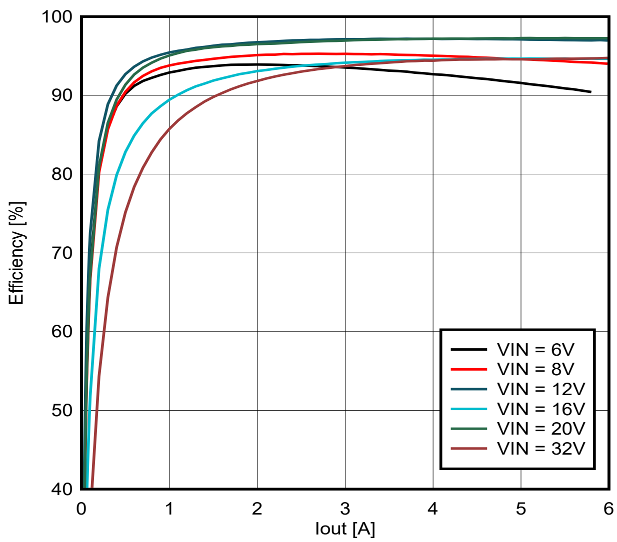

Figure 4-3. Efficiency Versus Output Current

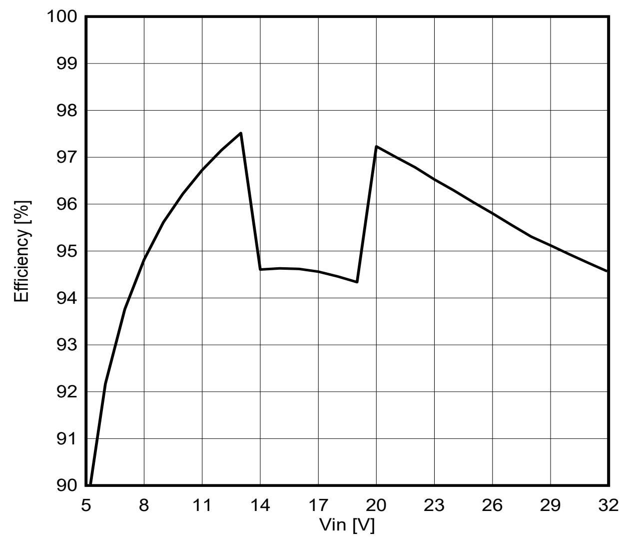

Figure 4-4. Efficiency Versus Input Voltage (I_{OUT} = 4.5 A)

4.3 Steady State Waveforms

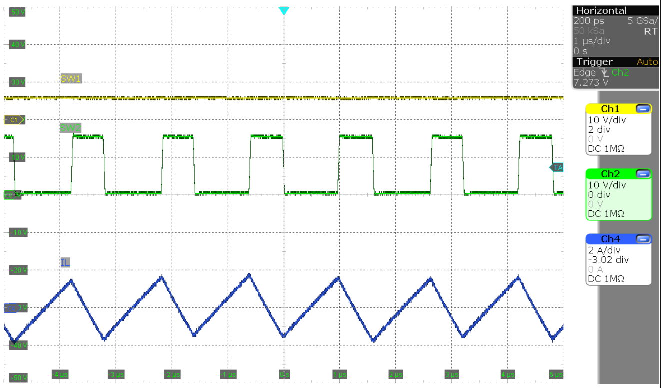

Figure 4-5. SW1, SW2, I_L (V_{IN} = 6 V, I_{OUT} = 0 A)

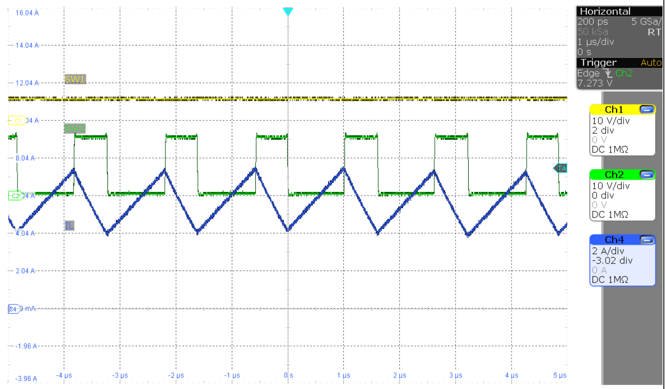

Figure 4-6. SW1, SW2, I_L (V_{IN} = 6 V, I_{OUT} = 2 A)

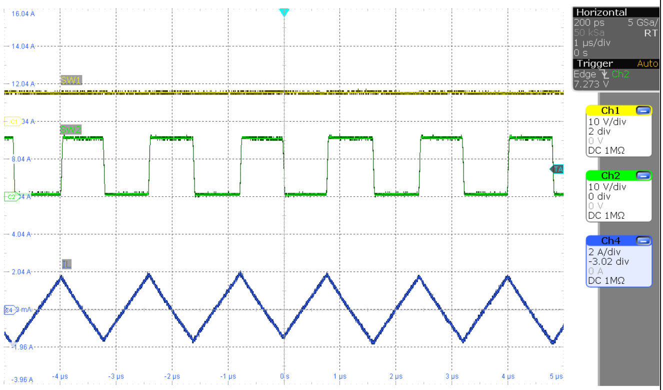

Figure 4-7. SW1, SW2, I_L (V_{IN} = 8 V, I_{OUT} = 0 A)

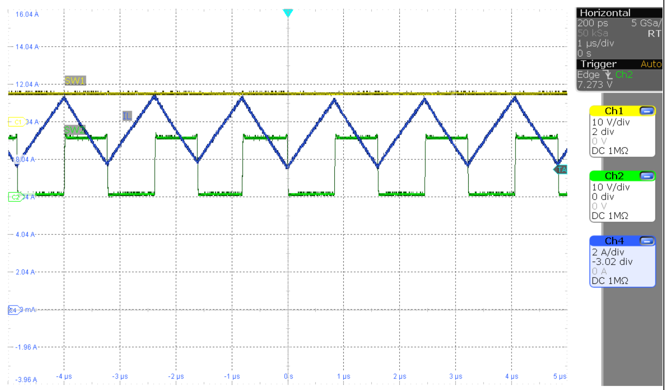

Figure 4-8. SW1, SW2, I_L (V_{IN} = 8 V, I_{OUT} = 4.5 A)

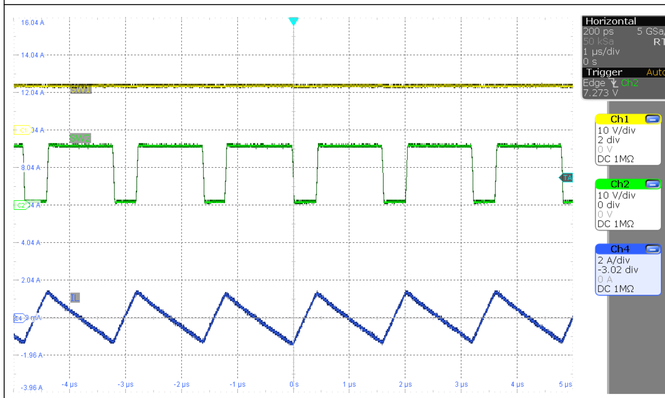

Figure 4-9. SW1, SW2, I_L (V_{IN} = 12 V, I_{OUT} = 0 A)

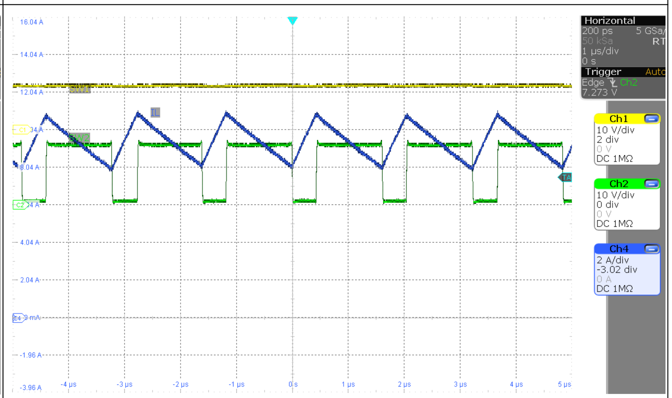

Figure 4-10. SW1, SW2, I_L (V_{IN} = 12 V, I_{OUT} = 6.8 A)

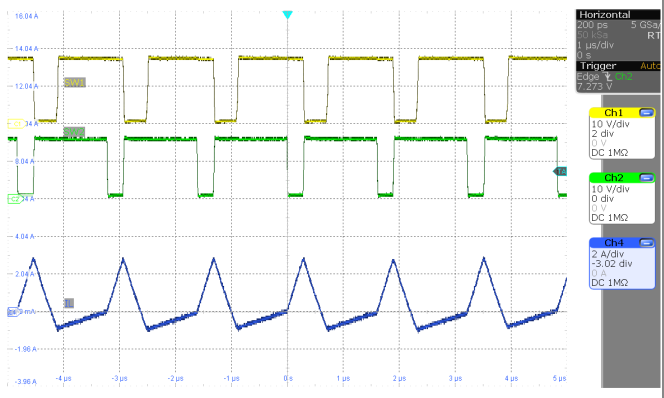

Figure 4-11. SW1, SW2, I_L (V_{IN} = 18 V, I_{OUT} = 0 A)

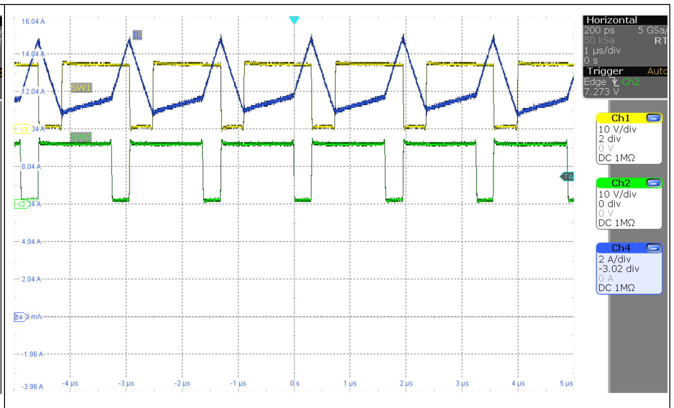

Figure 4-12. SW1, SW2, I_L (V_{IN} = 18 V, I_{OUT} = 9.4 A)

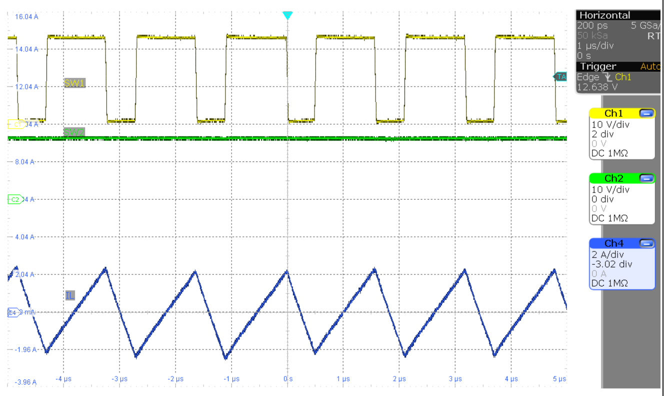

Figure 4-13. SW1, SW2, I_L (V_{IN} = 24 V, I_{OUT} = 0 A)

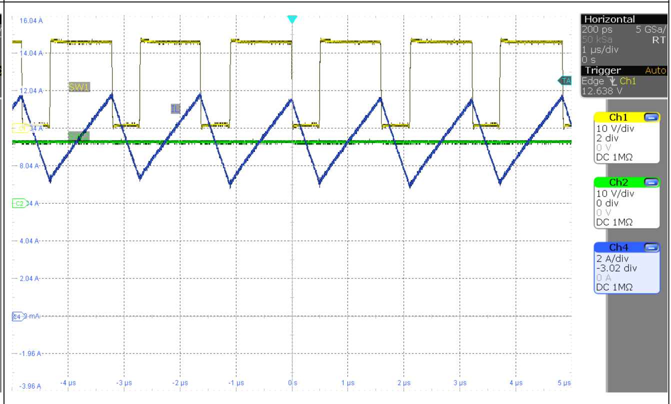

Figure 4-14. SW1, SW2, I_L (V_{IN} = 24 V, I_{OUT} = 9.4 A)

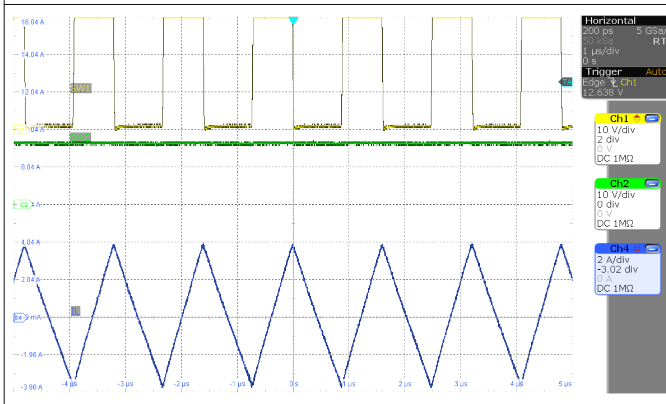

Figure 4-15. SW1, SW2, I_L (V_{IN} = 36 V, I_{OUT} = 0 A)

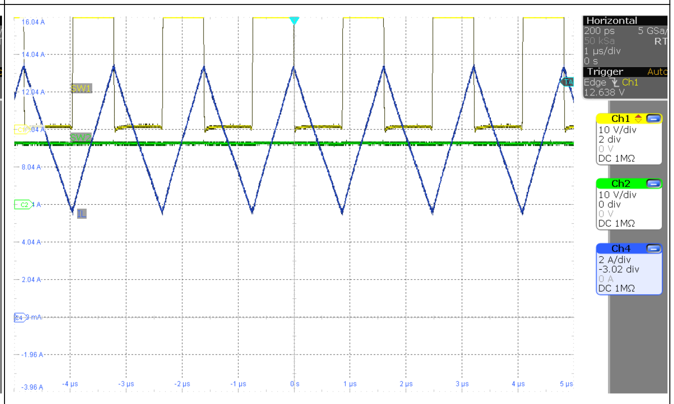

Figure 4-16. SW1, SW2, I_L (V_{IN} = 36 V, I_{OUT} = 9.4 A)

4.4 Step Load Response

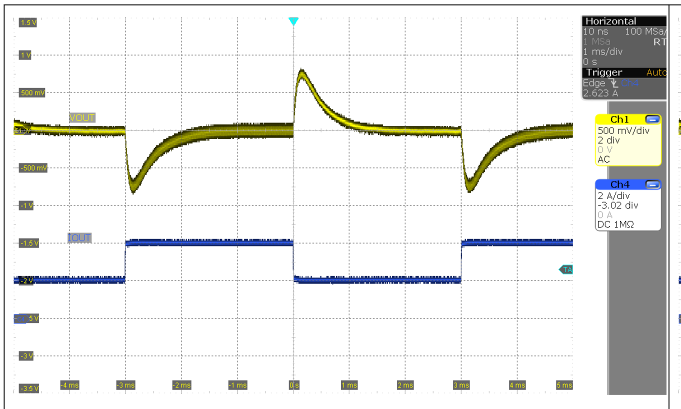

Figure 4-17. Load Step (V_{IN} = 7 V, I_{OUT} = 2 A–4 A)

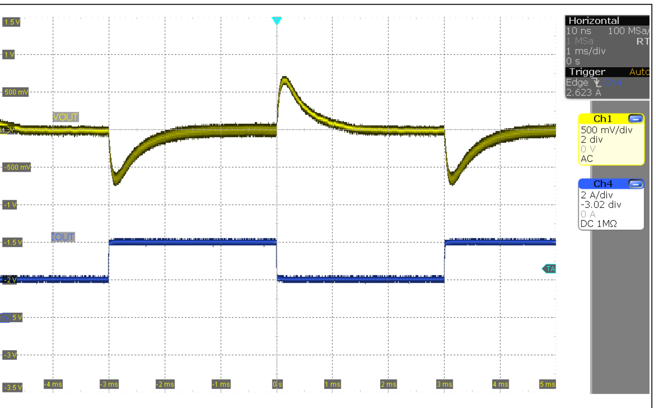

Figure 4-18. Load Step (V_{IN} = 8 V, I_{OUT} = 2 A–4 A)

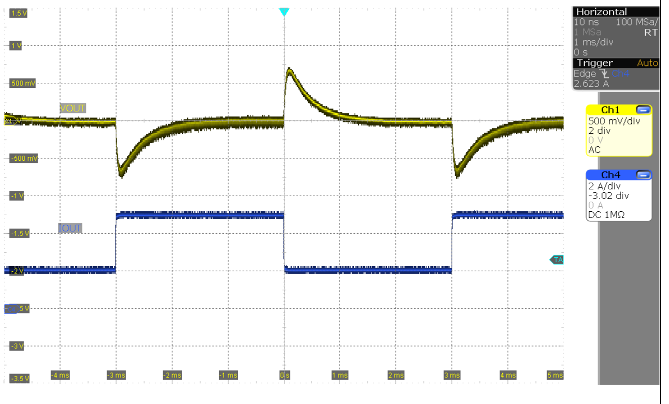

Figure 4-19. Load Step (V_{IN} = 12 V, I_{OUT} = 2 A–5 A)

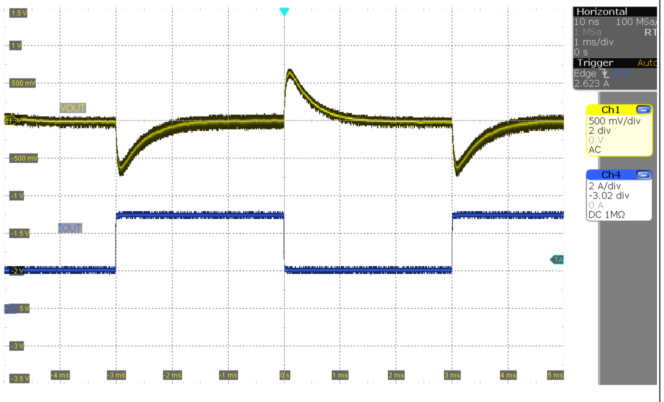

Figure 4-20. Load Step (V_{IN} = 18 V, I_{OUT} = 2 A–5 A)

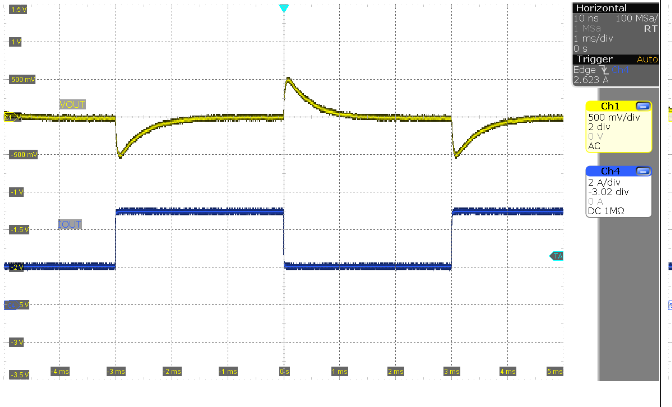

Figure 4-21. Load Step (V_{IN} = 24 V, I_{OUT} = 2 A–5 A)

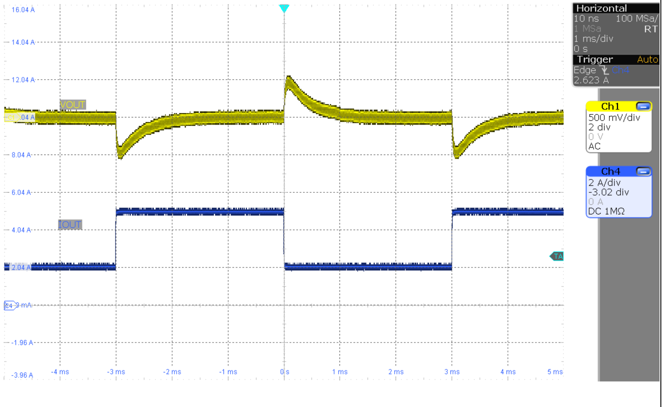

Figure 4-22. Load Step (V_{IN} = 36 V, I_{OUT} = 2 A–5 A)

5 Schematic

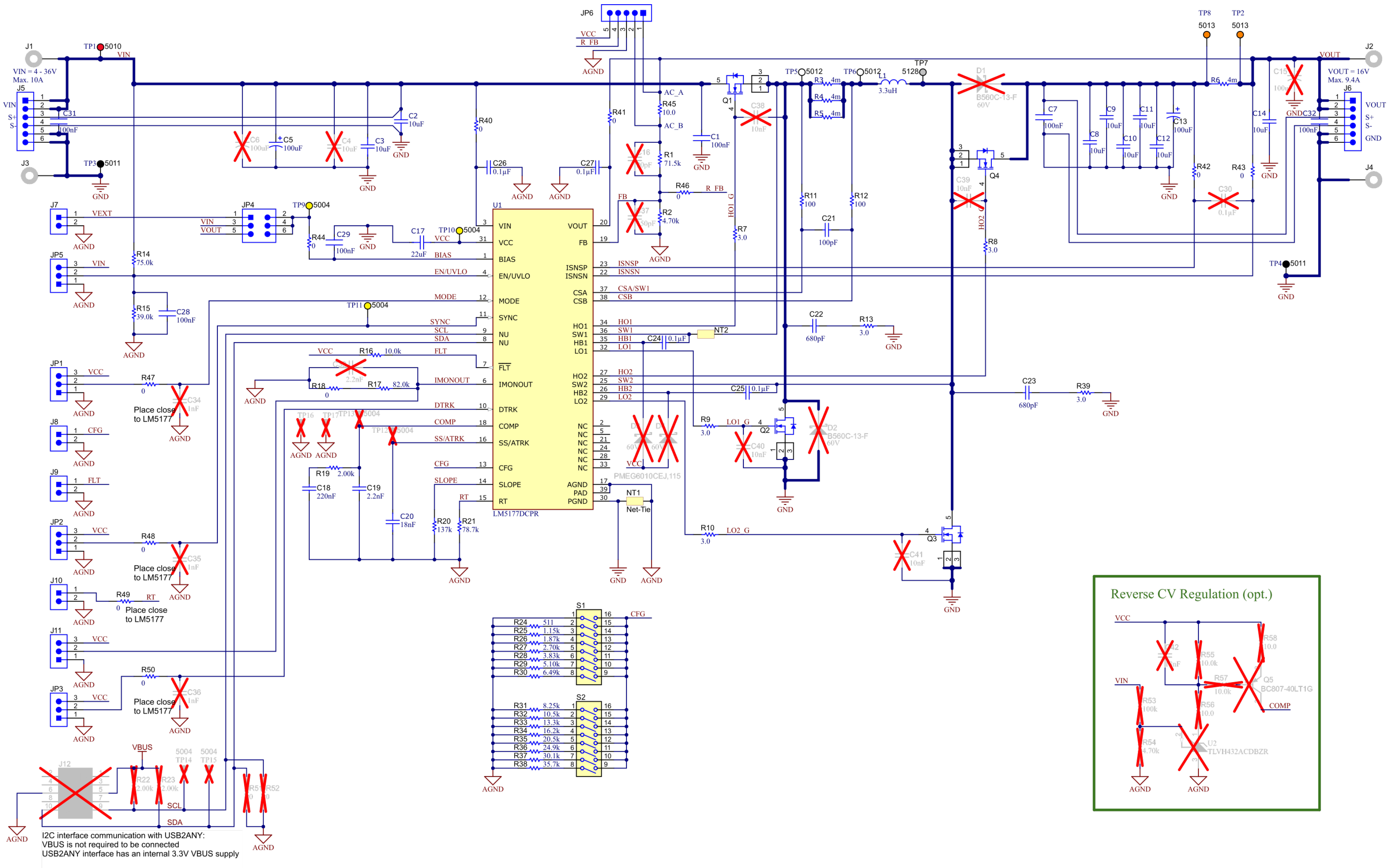

Figure 5-1. 4-Switch Buck-Boost Converter Schematic

6 Optional Components

Table 6-1 shows a list and function of optional components placed in the schematic

Table 6-1. Optional Components

Component	Function
R47 / C34 R48 / C35 R50 / C36	Filter for digital signals; can be added in a noisy setup. If not used, add 0 Ohm for the resistors.
J12 / R22 / R23 / R51 /R52	I2C interface - not available for the LM5177. Pins are used as logic level output of HO1 and HO2, see data sheet.
R18 / R17 / C33	Footprint for filter circuit on IMONOUT, see data sheet for component selection to configure that function.
D3 / D4	Placeholder for external BOOT diodes.
R42 / R43 / C30	Input filter for ISNS input.
Reverse CV Regulation Section	Can add CV control in reverse CC Mode.

7 Board Layout

Figure 7-1 through Figure 7-6 show the design of the LM5177EVM-HP RevC PCB.

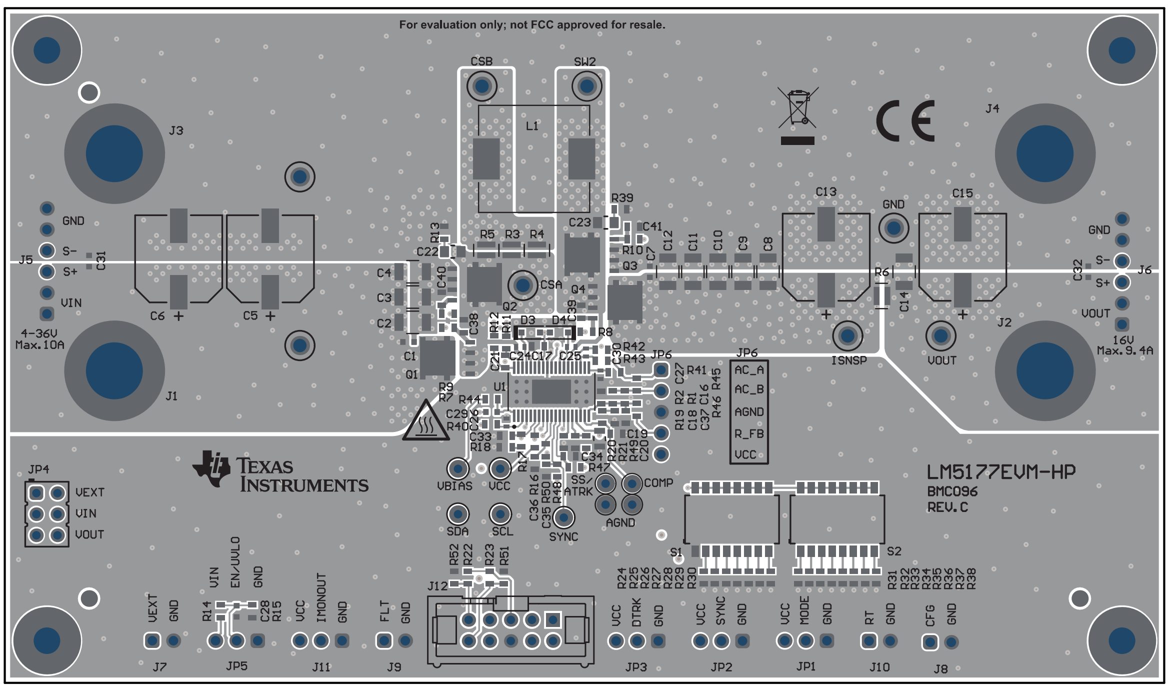

Figure 7-1. Top Silkscreen

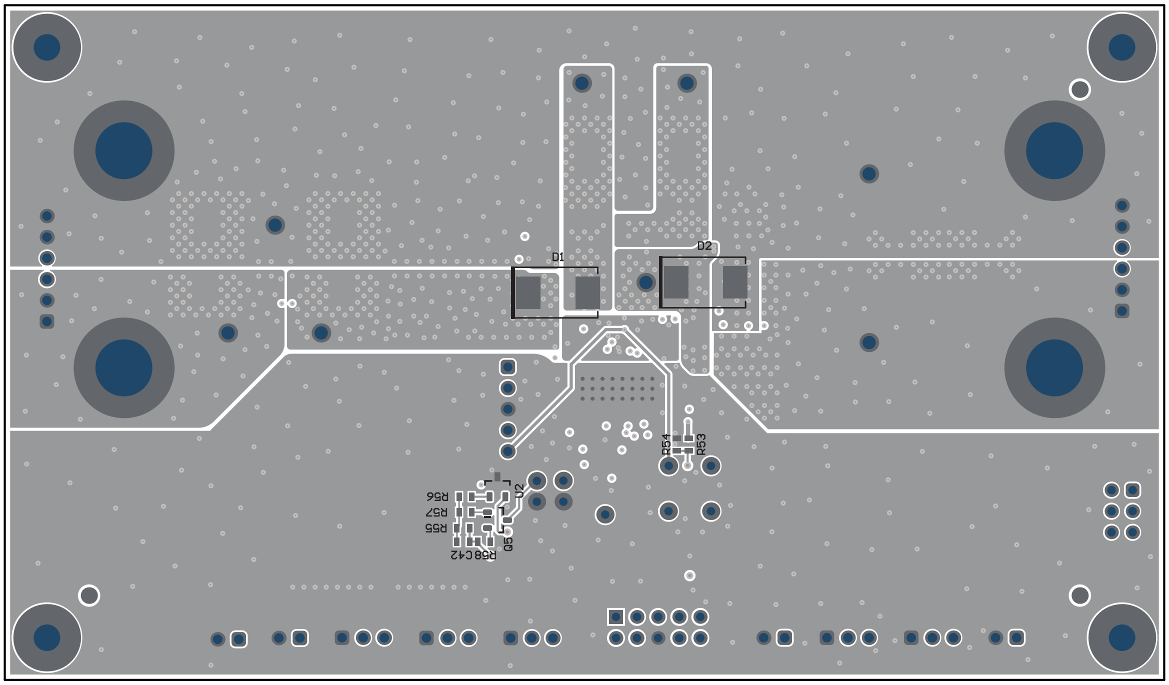

Figure 7-2. Bottom Silkscreen

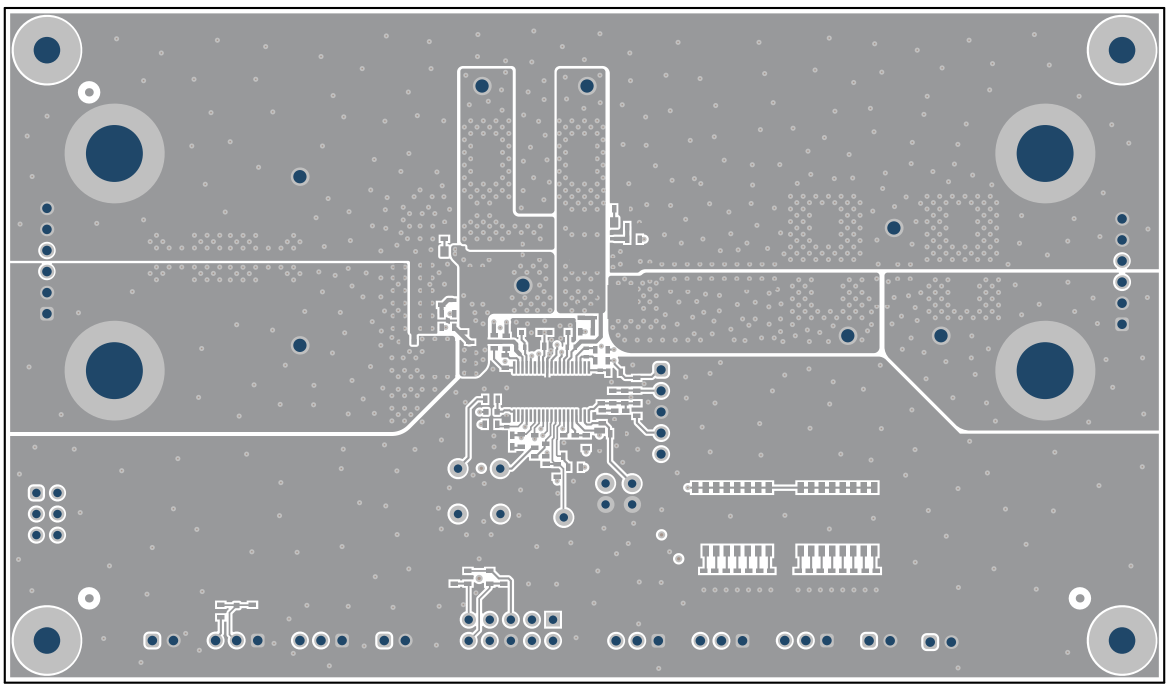

Figure 7-3. Top Layer

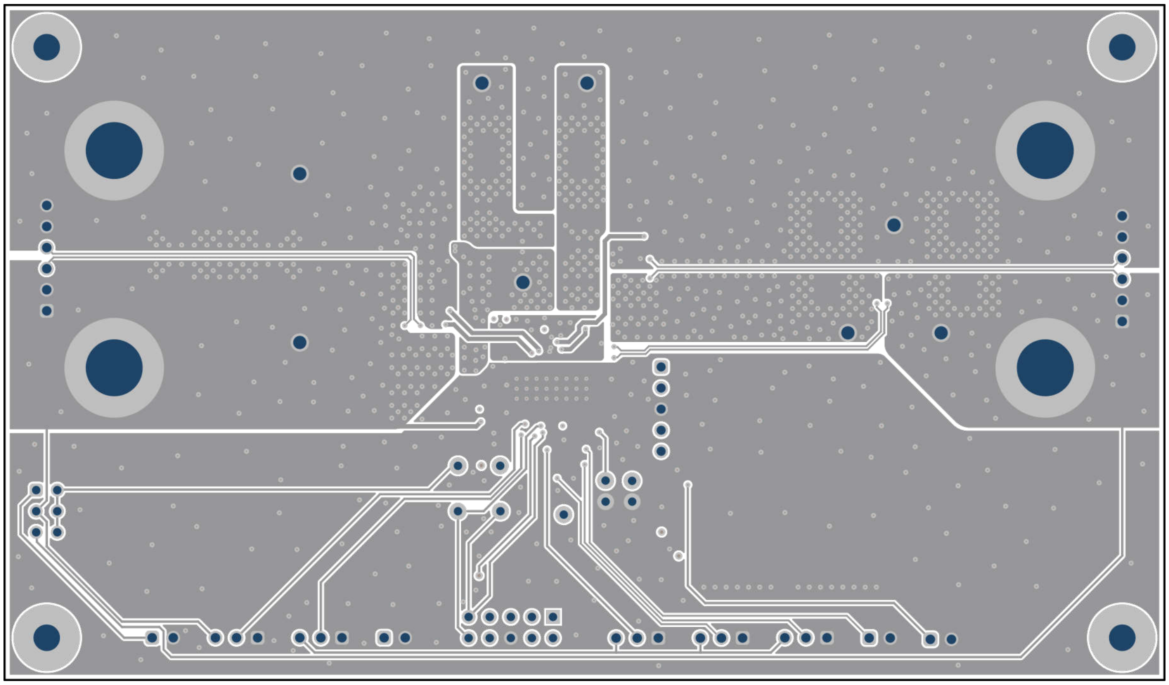

Figure 7-4. Mid-Layer 1

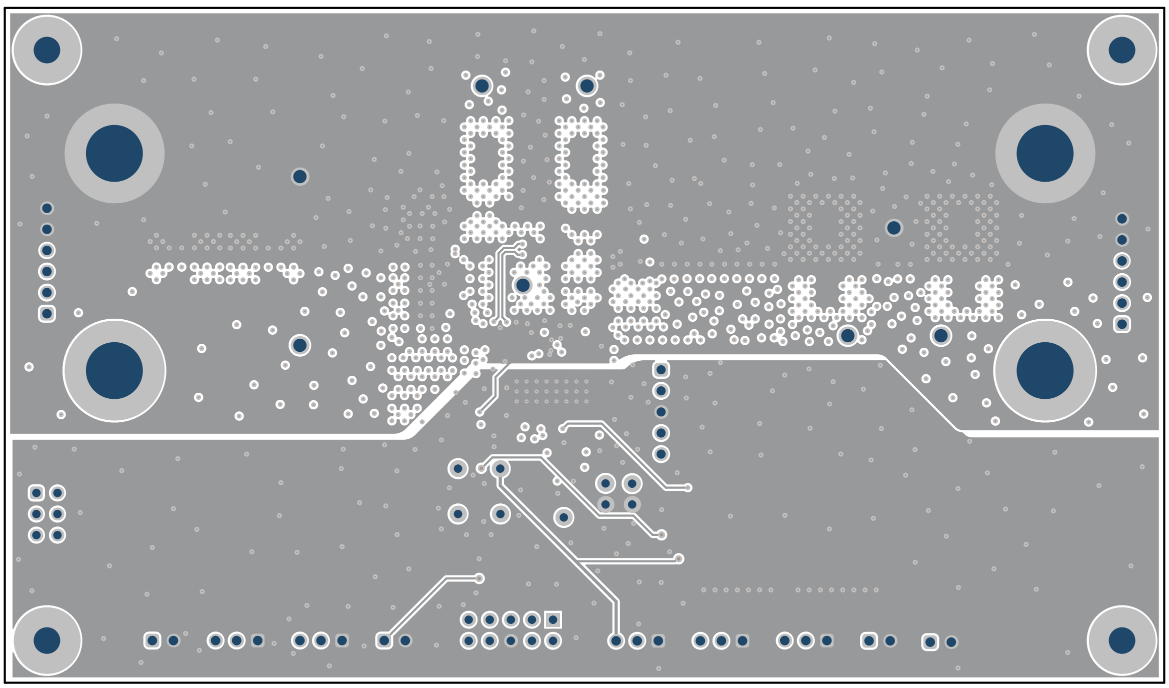

Figure 7-5. Mid-Layer 2

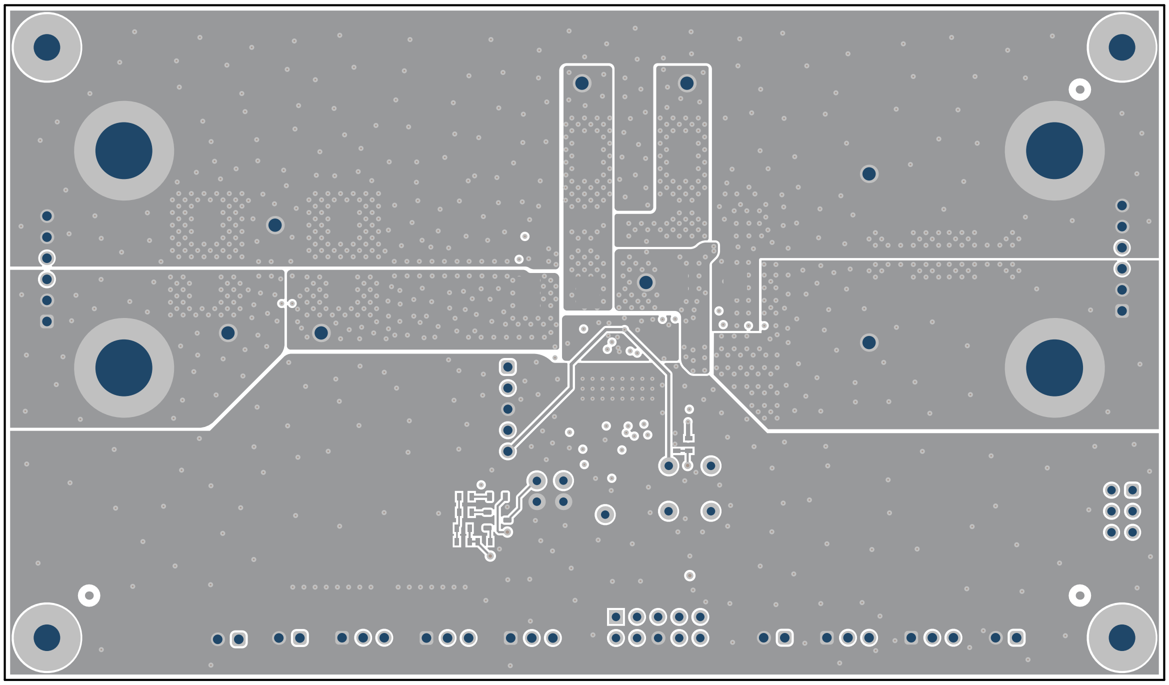

Figure 7-6. Bottom Layer

8 Bill of Materials

Table 8-1. Bill of Materials

Designator	Quantity	Description	Part Number	Manufacturer
C1, C7, C28, C29, C31, C32	6	0.1µF ±10% 50 V Ceramic Capacitor X8L 0603 (1608 Metric)	GCM188L81H104KA57D	Murata Electronics North America
C2, C3, C8, C9, C10, C11, C12, C14	8	Ceramic Capacitor for Automotive 10uF ±10% 50VDC X7S 1210 Embossed T/R	GCM32EC71H106KA03L	Murata
C5, C13	2	CAP, Aluminum Polymer, 100 uF, 63 V, +/- 20%, 0.024 ohm, SMD, 2-Leads, Dia 10.5mm, Pin Spacing 8 mm SMD	PCR1J101MCL1GS	Nichicon
C17	1	CAP, CERM, 47 uF, 6.3 V, +/- 20%, X5R, 0603	GRM188R60J476ME15D	Murata
C18	1	CAP, CERM, 0.22 uF, 50 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E3X7R1H224K080AB	TDK
C19	1	CAP, CERM, 2200 pF, 100 V, +/- 5%, X7R, 0603	06031C222JAT2A	AVX
C20	1	Ceramic Capacitor for Automotive 18 nF ±5% 50VDC C0G 0805 Embossed T/R	GCM21B5C1H183JA16L	Murata
C21	1	CAP, CERM, 100 pF, 50 V,+/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	GCM1885C1H101JA16J	Murata
C22, C23	2	CAP, CERM, 680 pF, 50 V, +/- 5%, C0G/NP0, 0805	GRM2165C1H681JA01D	Murata
C24, C25, C26, C27	4	CAP, CERM, 0.1 µF, 50 V,+/- 10%, X7R, 0402	0402BB104KW500	Passive Plus
J1, J2, J3, J4	4	Standard Banana Jack, Uninsulated, 15A	108-0740-001	Cinch Connectivity
J5, J6	2	Header, 2.54 mm, 6x1, Gold, TH	61300611121	Wurth Elektronik
J7, J8, J9, J10	4	Header, 2.54 mm, 2x1, Gold, TH	61300211121	Wurth Elektronik
J11, JP1, JP2, JP3, JP5	5	Header, 2.54 mm, 3x1, Gold, TH	61300311121	Wurth Elektronik
JP4	1	Header, 2.54mm, 3x2, Gold, TH	HTSW-103-07-G-D	Samtec
JP6	1	Header, 2.54mm, 5x1, Gold, TH	61300511121	Wurth Elektronik
L1	1	Inductor, Shielded, Powdered Iron, 1.8 uH, 24 A, 0.0032 ohm, SMD	IHLP5050FDER1R8M01	Vishay-Dale
Q1, Q2, Q3, Q4	4	MOSFET, N-CH, 40 V, 75 A, PowerPAK_SO-8L	SQJ422EP-T1-GE3	Vishay-Siliconix
R1	1	RES, 71.5 k, 1%, 0.1 W, 0603	RC0603FR-0771K5L	Yageo
R2	1	RES, 4.70 k, 1%, 0.1 W, 0603	RC0603FR-074K7L	Yageo
R3, R4, R5, R6	4	4 mOhms ±1% 1W Chip Resistor Wide 0805 (2012 Metric), 0508 Automotive AEC-Q200, Current Sense Metal Foil	KRL2012E-M-R004-F-T5	Susumu

Table 8-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
R7, R8, R9, R10, R13, R39	6	RES, 3.0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033R00JNEA	Vishay-Dale
R11, R12	2	RES, 100, 1%, 0.25 W, AEC-Q200 Grade 0, 0603	CRCW0603100RFKEAHP	Vishay-Dale
R14	1	RES, 75.0 k, 1%, 0.1 W, 0603	RC0603FR-0775KL	Yageo
R15	1	RES, 39.0 k, 1%, 0.1 W, 0603	RC0603FR-0739KL	Yageo
R16	1	RES, 10.0 k, 0.1%, 0.1 W, 0603	RT0603BRD0710KL	Yageo America
R17	1	RES, 82.0 k, 1%, 0.1 W, 0603	RC0603FR-0782KL	Yageo
R18, R40, R41, R42, R43, R44, R46, R47, R48, R49, R50	11	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R19	1	RES, 2.00 k, 1%, 0.1 W, 0603	RC0603FR-072KL	Yageo
R20	1	RES, 68.1 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060368K1FKEA	Vishay-Dale
R21	1	RES, 78.7 k, 1%, 0.1 W, 0603	RC0603FR-0778K7L	Yageo
R24	1	RES, 511, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603511RFKEA	Vishay-Dale
R25	1	RES, 1.15 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06031K15FKEA	Vishay-Dale
R26	1	RES, 1.87 k, 1%, 0.1 W, 0603	RC0603FR-071K87L	Yageo
R27	1	RES, 2.70 k, 1%, 0.1 W, 0603	RC0603FR-072K7L	Yageo
R28	1	RES, 3.83 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033K83FKEA	Vishay-Dale
R29	1	RES, 5.10 k, 1%, 0.1 W, 0603	RC0603FR-075K1L	Yageo
R30	1	RES, 6.49 k, 1%, 0.1 W, 0603	RC0603FR-076K49L	Yageo
R31	1	RES, 8.25 k, 1%, 0.1 W, 0603	RC0603FR-078K25L	Yageo
R32	1	RES, 10.5 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K5FKEA	Vishay-Dale
R33	1	RES, 13.3 k, 1%, 0.1 W, 0603	RC0603FR-0713K3L	Yageo
R34	1	RES, 16.2 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060316K2FKEA	Vishay-Dale
R35	1	RES, 20.5 k, 1%, 0.1 W, 0603	RC0603FR-0720K5L	Yageo
R36	1	RES, 24.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060324K9FKEA	Vishay-Dale
R37	1	RES, 30.1 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060330K1FKEA	Vishay-Dale
R38	1	RES, 35.7 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060335K7FKEA	Vishay-Dale
R45	1	RES, 10.0, 1%, 0.1 W, 0603	RC0603FR-0710RL	Yageo
S1, S2	2	Switch, SPST, 8 Pos, 25 mA, 24VDC, SMD	218-8LPST	CTS Electrocomponents

Table 8-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
SH-JP1, SH-JP2, SH-JP3, SH-JP4, SH-JP5	5	Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
TP1	1	Test Point, Multipurpose, Red, TH	5010	Keystone Electronics
TP2, TP8	2	Test Point, Multipurpose, Orange, TH	5013	Keystone Electronics
TP3, TP4	2	Test Point, Multipurpose, Black, TH	5011	Keystone Electronics
TP5, TP6	2	Test Point, Multipurpose, White, TH	5012	Keystone Electronics
TP7	1	Test Point, Multipurpose, Grey, TH	5128	Keystone Electronics
TP9, TP10, TP11	3	Test Point, Miniature, Yellow, TH	5004	Keystone Electronics
U1	1	Wide VIN Bidirectional 4 Switch Buck-Boost Controller	LM5177DCPR	Texas Instruments
C4	0	Ceramic Capacitor for Automotive 10uF ±10% 50VDC X7S 1210 Embossed T/R	GCM32EC71H106KA03L	Murata
C6, C15	0	CAP, Aluminum Polymer, 100 uF, 63 V, +/- 20%, 0.024 ohm, SMD, 2-Leads, Dia 10.5mm, Pin Spacing 8 mm SMD	PCR1J101MCL1GS	Nichicon
C16	0	CAP, CERM, 20 pF, 100 V, +/- 5%, C0G/NP0, 0603	GRM1885C2A200JA01D	Murata
C30	0	CAP, CERM, 0.1 µF, 50 V,+/- 10%, X7R, 0402	0402BB104KW500	Passive Plus
C33	0	CAP, CERM, 2200 pF, 100 V, +/- 5%, X7R, 0603	06031C222JAT2A	AVX
C34, C35, C36	0	CAP, CERM, 1000 pF, 100 V, +/- 5%, X7R, 0603	06031C102JAT2A	AVX
C37	0	CAP, CERM, 150 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H151JA01D	Murata
C38, C39, C40, C41	0	CAP, CERM, 0.01 uF, 100 V, +/- 10%, X7R, 0603	GRM188R72A103KA01D	Murata
C42	0	CAP, CERM, 0.018 uF, 100 V, +/- 10%, X7R, 0603	C0603C183K1RACTU	Kemet
D1, D2	0	Diode, Schottky, 60 V, 5 A, SMC	B560C-13-F	Diodes Inc.
D3, D4	0	Diode, Schottky, 60 V, 1 A, SOD-323F	PMEG6010CEJ,115	Nexperia
FID1, FID2, FID3, FID4, FID5, FID6	0	Fiduciary mark. There is nothing to buy or mount.	N/A	N/A
H1, H2, H3, H4	0	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	0	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
J12	0	Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	N2510-6002-RB	3M
Q5	0	Transistor, PNP, 45 V, 0.5 A, AEC-Q101, SOT-23	BC807-40LT1G	ON Semiconductor

Table 8-1. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
R22, R23	0	RES, 2.00 k, 1%, 0.1 W, 0603	RC0603FR-072KL	Yageo
R51, R52	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R53	0	RES, 100 k, 1%, 0.1 W, 0603	RC0603FR-07100KL	Yageo
R54	0	RES, 4.70 k, 1%, 0.1 W, 0603	RC0603FR-074K7L	Yageo
R55, R57	0	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K0FKEA	Vishay-Dale
R56, R58	0	RES, 10.0, 1%, 0.1 W, 0603	RC0603FR-0710RL	Yageo
TP12, TP13, TP14, TP15	0	Test Point, Miniature, Yellow, TH	5004	Keystone Electronics
TP16, TP17	0	Test Point, Miniature, Black, TH	5001	Keystone Electronics
U2	0	Low-Voltage Adjustable Precision Shunt Regulator, 129 ppm / degC, 80 mA, 0 to 70 degC, 3-pin SOT-23 (DBZ), Green (RoHS and no Sb/Br)	TLVH432ACDBZR	Texas Instruments

Table 8-2. Alternate Parts

Designator	Part Number	Alternate Part Number
C24, C25, C26, C27	0402BB104KW500	CL10B104JB8NNNC GRM155R71H104ME14D GRM155R71H104KE14D
R24	CRCW0603511RFKEA	RMCF0603FT511R
C20	GCM21B5C1H183JA16L	GRM21B5C1H183JA01L GRM21B5C1H183JA01K
Q1, Q2, Q3, Q4	SQJ422EP-T1-GE3	BSC032N04LS

9 Revision History

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

Changes from Revision B (March 2023) to Revision C (October 2024) **Page**

- Updated Table 2-4 6

Changes from Revision A (January 2023) to Revision B (March 2023)	Page

- Changed all figures in *Test Setup and Procedure* section 7
- Changed schematics in *Schematic* section 12
- Added *Optional Components* section 13
- Changed all images in *Board Layout* section 13
- Changed Table 8-1 17
- Added Table 8-2 to *Bill of Materials* section 17

Changes from Revision * (April 2022) to Revision A (January 2023)	Page

- Changed LM5177EVM-HP (Schematic, Layout, and BOM) 12

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