EVM User's Guide: LM5177EVM-HP

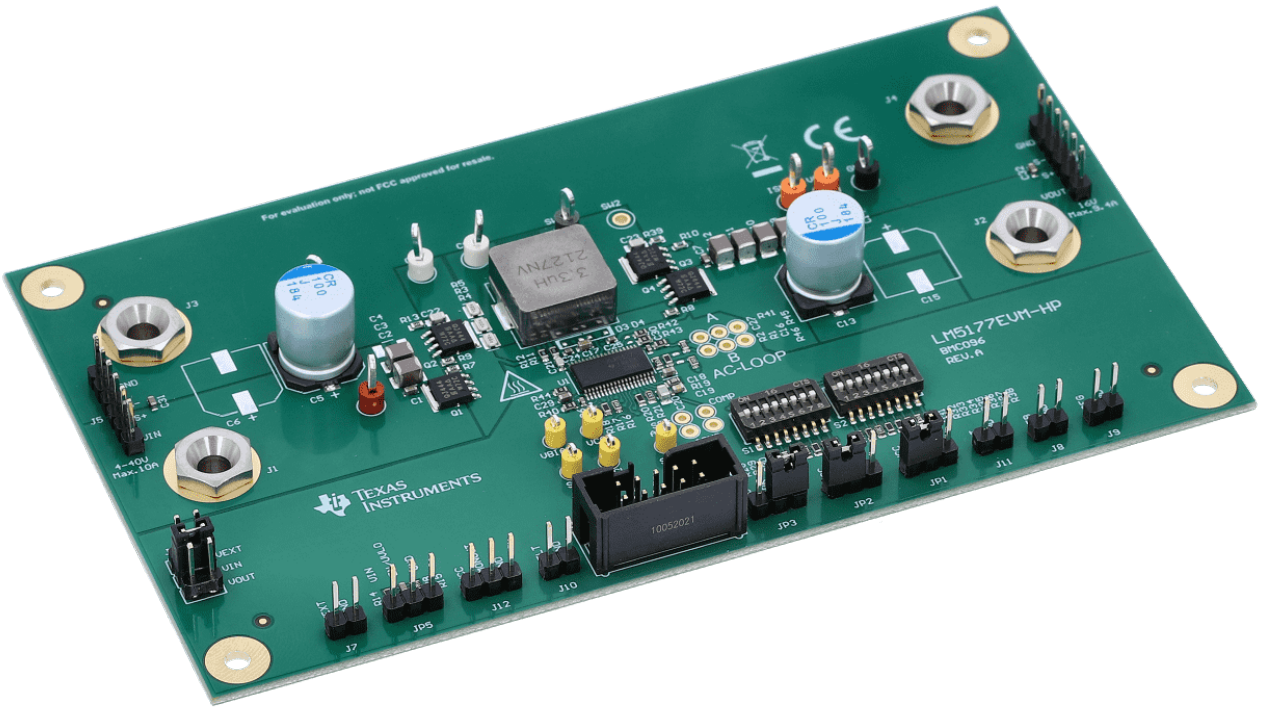
LM5177 Buck-Boost Controller Evaluation Module

Description

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

Features

- 4.2V to 36V input voltage range
- 16V with up to 9.4A (150W) output voltage
- High efficiency synchronous buck-boost conversion
- Easy access to configuration features
- Flexible design using standard 5mm x 6mm FETs



1 Evaluation Module Overview

1.1 Introduction

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.

1.2 Kit Contents

- One LM5177EVM-HP PCB
- EVM Disclaimer Read Me

1.3 Specification

Table 1-1. Board Specifications

Parameter	Value
Input voltage	4.2V to 36V
Output voltage	16V
Maximum output current	9.4A
Default switching frequency	400kHz
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 Hardware

2.1 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.

2.1.1 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)

2.1.2 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.	

2.1.3 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

2.1.4 Selection Switch Descriptions

2.1.4.1 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.

2.1.5 Current Monitor and Current Limiter Configuration

The EVM is can be adopted support Current Monitor and Current Limit function. The default setup is done for Current Monitoring.

To select the required components for IMONOUT and how to set various operation modes, refer to the LM51770 BuckBoost Quickstart Calculator Tool.

2.1.5.1 Current Monitor and Current Limiter Configuration

For the current monitoring, these settings need to be done:

- CFG setting with Current limiter not enabled
- IMONOUT jumper J12 removed
- IMONOUT with resistor to GND - see Figure 2-1

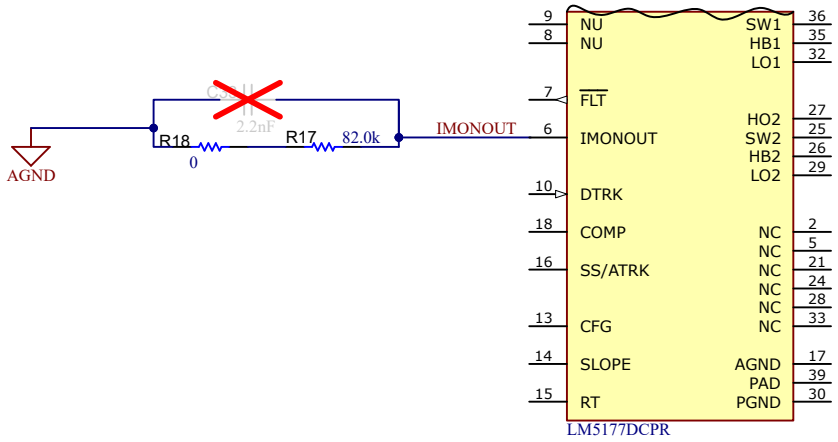


Figure 2-1. IMONOUT components for current monitor

2.1.5.2 Current Limiter Configuration

For the current limiting, the settings are shown below. Refer to Figure 2-3.

- CFG setting with current limiter enabled
- IMONOUT jumper J12 removed
- SYNC connected to VCC for forward current limit
- IMONOUT with resistor and capacitor in series to GND - see Figure 2-2

Note

EMV shows only placeholder for components. Names and symbols do not always reflect the component type and value which are placed there. For example, CR18: 2.2nF and R17: 700Ω

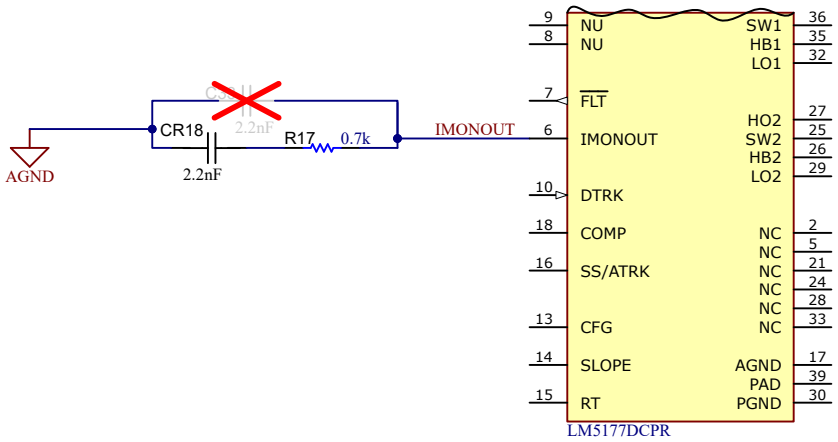


Figure 2-2. IMONOUT Components For Current Limit

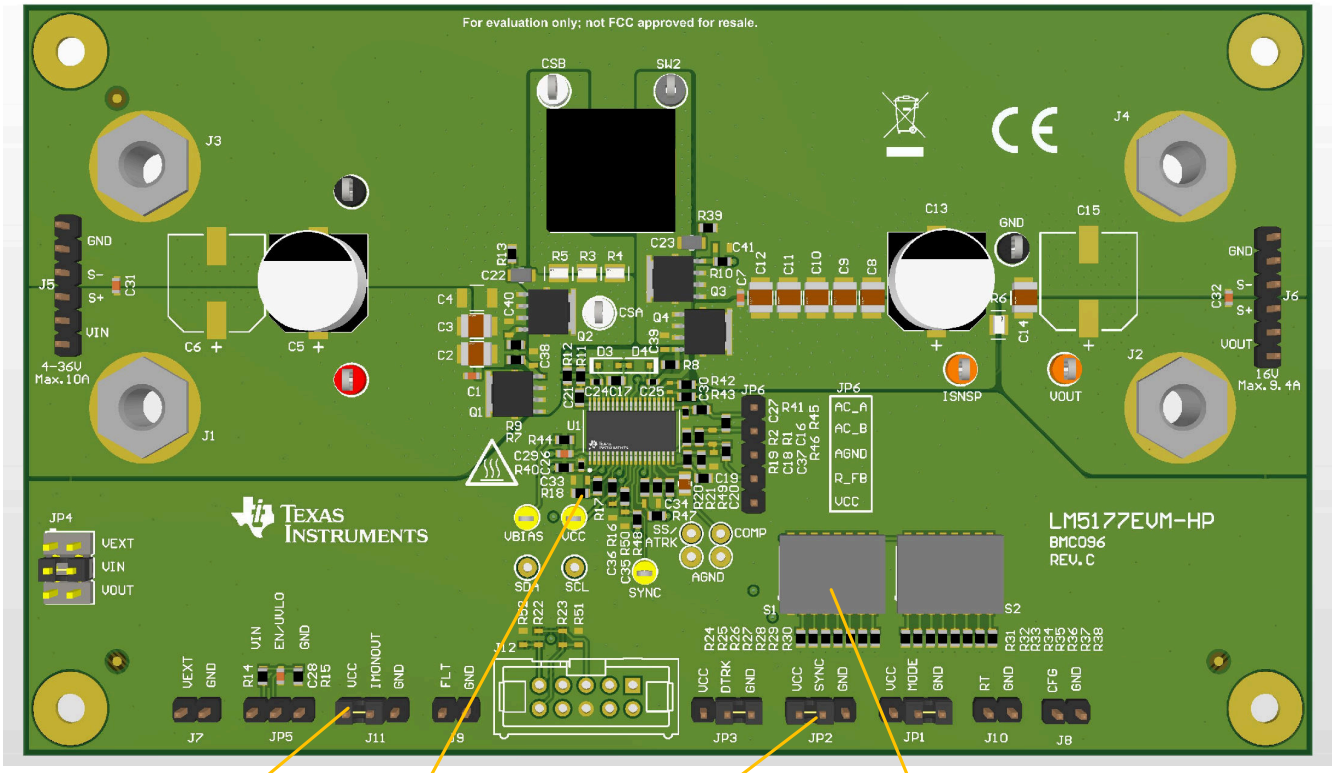


Figure 2-3. LM5177 EVM Current Limit Setup

2.2 Test Setup and Procedure

2.2.1 Test Setup

Figure 2-4 shows a typical test setup to evaluate the LM5177EVM-HP.

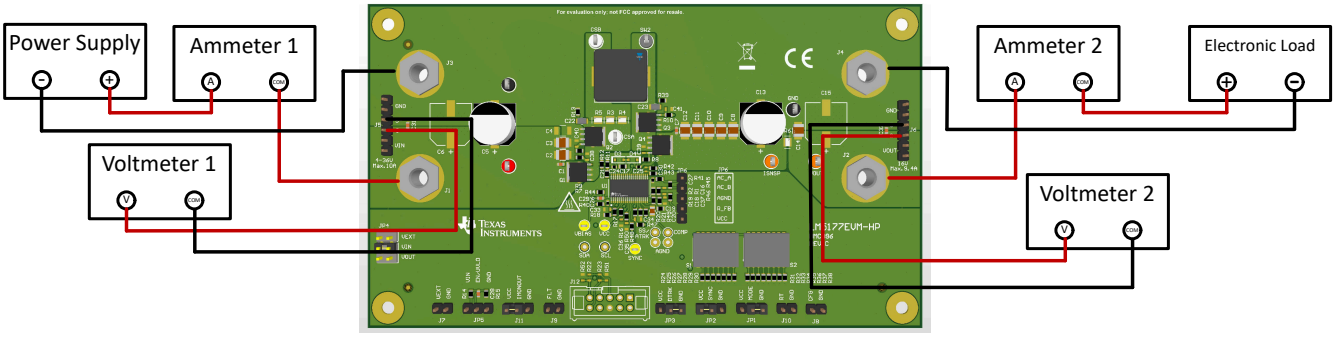


Figure 2-4. Typical EVM Connection Diagram

2.2.2 Test Procedure

1. Set the power supply current limit to 10A. 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 16V and the electronic load to 0.1A. The electronic load voltage must be in regulation with a nominal 16V 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 16V output as the load is increased up to 9.4A.
5. Slowly sweep the input voltage from 16V to 36V. The output voltage must remain in regulation with a nominal 16V output.
6. Decrease the load to 2.5A.
7. Slowly sweep the input voltage from 36V to 5V. The output voltage must remain in regulation with a nominal 16V output.
8. Decrease the input voltage down to 0V to shut down the buck-boost converter, and then turn off the load.

2.2.3 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.

3 Implementation Results

3.1 Test Data and Performance Curves

3.1.1 Thermal Performance

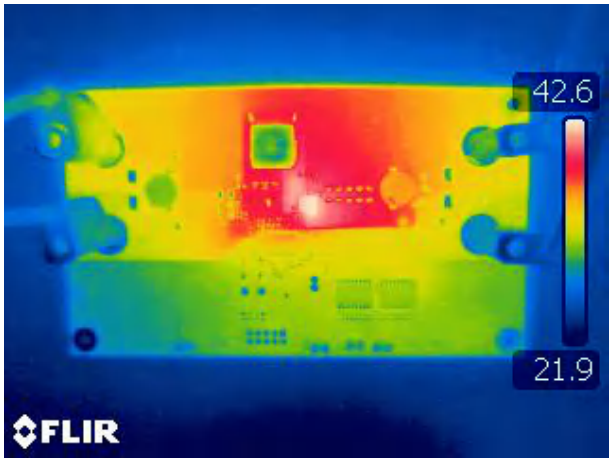


Figure 3-1. Thermal Image: V_{IN} = 4.2V, I_{OUT} = 2.2A, No Forced Air Cooling

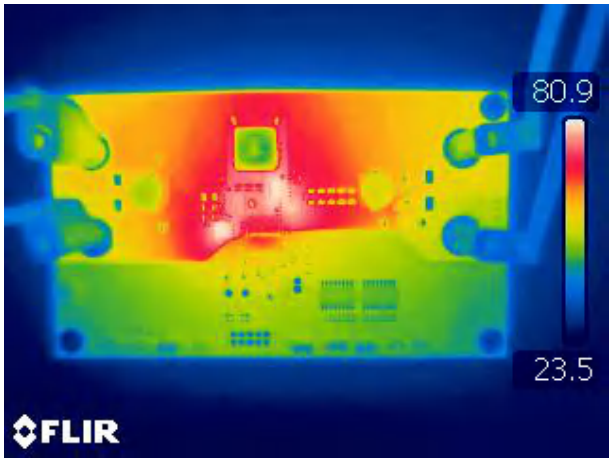


Figure 3-2. Thermal Image: V_{IN} = 16V, I_{OUT} = 9.4A, No Forced Air Cooling

3.1.2 Efficiency

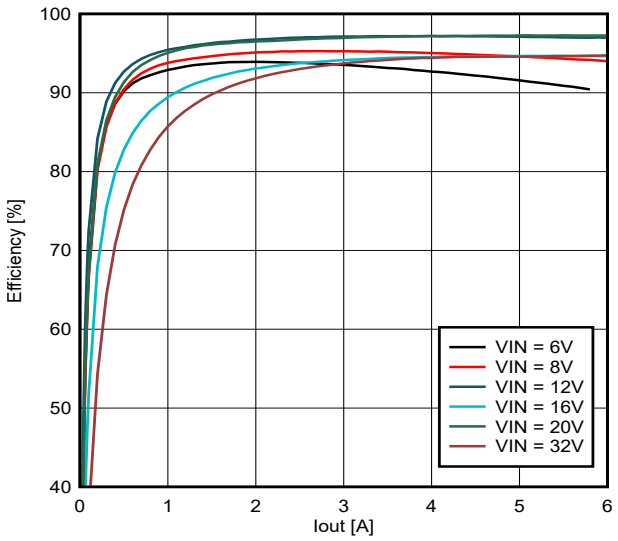


Figure 3-3. Efficiency Versus Output Current

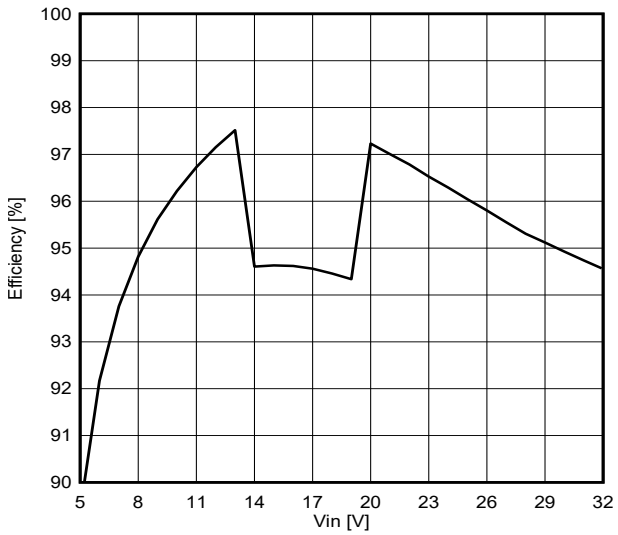


Figure 3-4. Efficiency Versus Input Voltage (I_{OUT} = 4.5A)

3.1.3 Steady State Waveforms

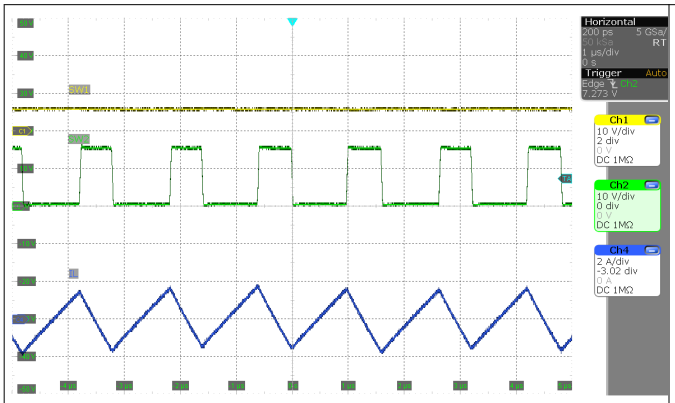


Figure 3-5. SW1, SW2, I_L (V_{IN} = 6V, I_{OUT} = 0A)

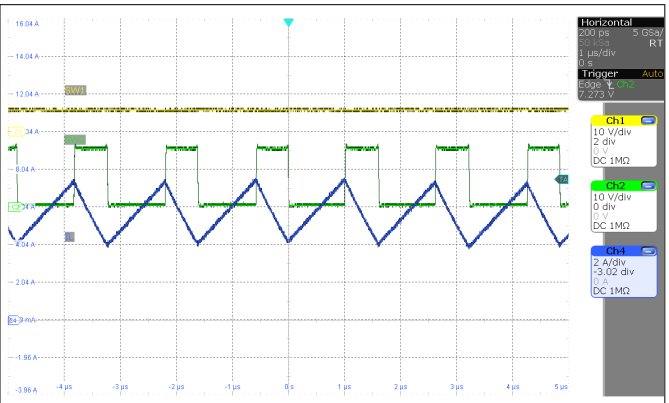


Figure 3-6. SW1, SW2, I_L (V_{IN} = 6V, I_{OUT} = 2A)

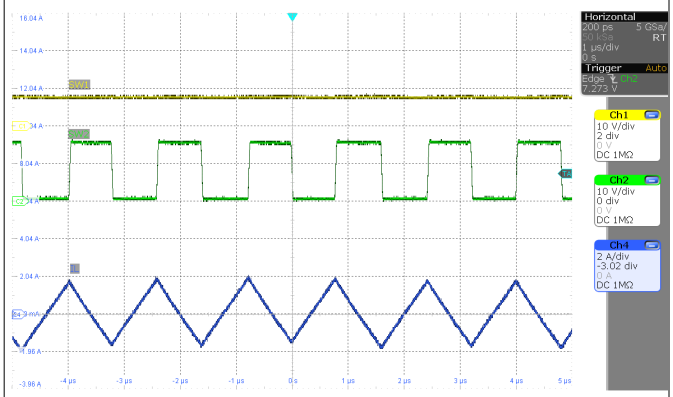


Figure 3-7. SW1, SW2, I_L (V_{IN} = 8V, I_{OUT} = 0A)

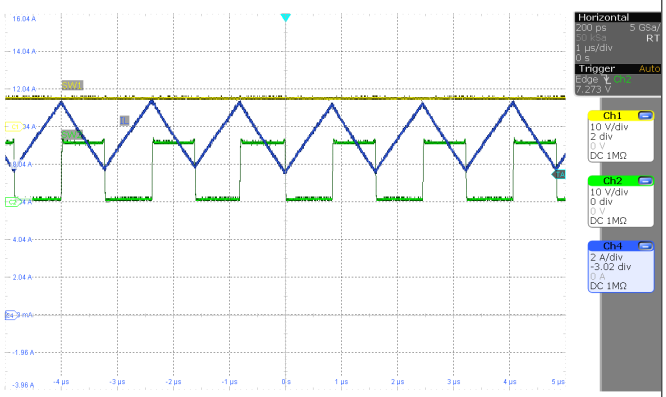


Figure 3-8. SW1, SW2, I_L (V_{IN} = 8V, I_{OUT} = 4.5A)

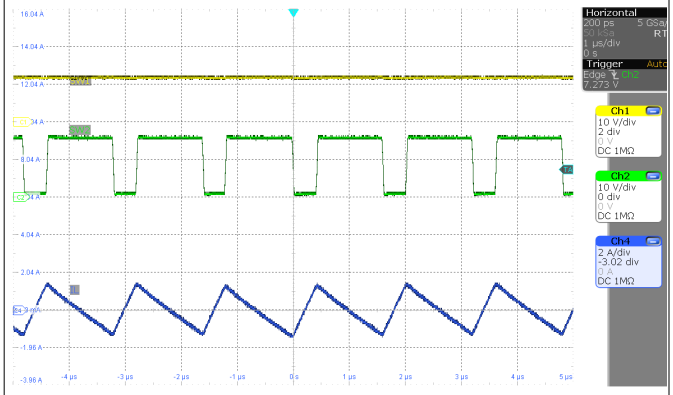


Figure 3-9. SW1, SW2, I_L (V_{IN} = 12V, I_{OUT} = 0A)

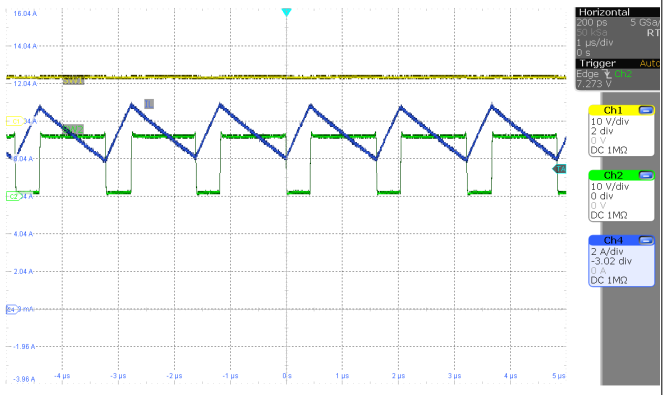


Figure 3-10. SW1, SW2, I_L (V_{IN} = 12V, I_{OUT} = 6.8A)

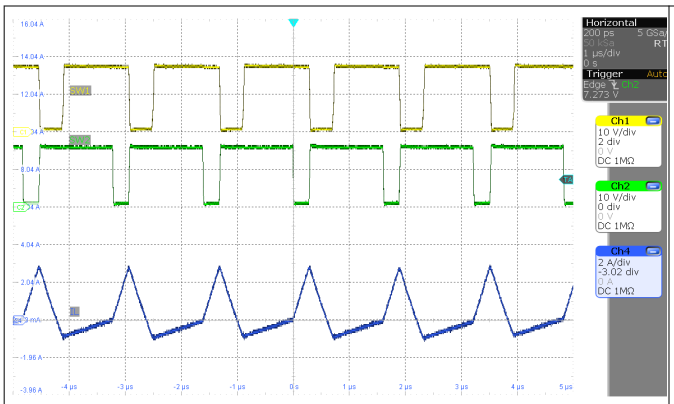


Figure 3-11. SW1, SW2, I_L (V_{IN} = 18V, I_{OUT} = 0A)

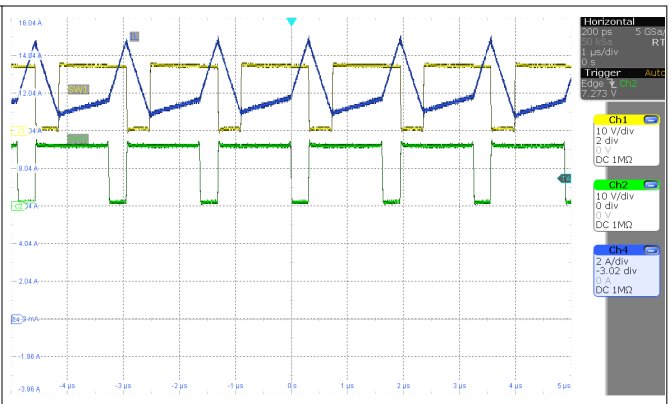


Figure 3-12. SW1, SW2, I_L (V_{IN} = 18V, I_{OUT} = 9.4A)

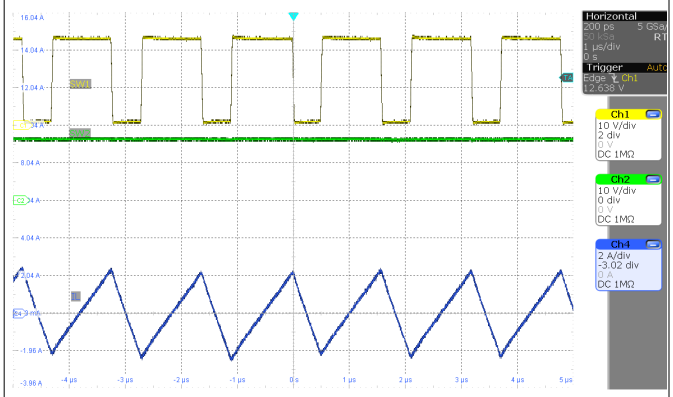


Figure 3-13. SW1, SW2, I_L (V_{IN} = 24V, I_{OUT} = 0A)

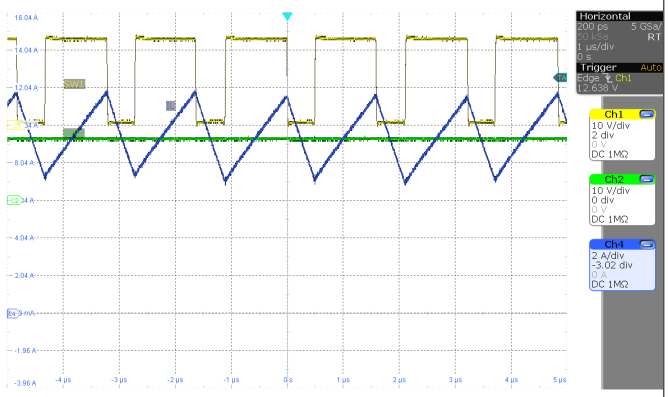


Figure 3-14. SW1, SW2, I_L (V_{IN} = 24V, I_{OUT} = 9.4A)

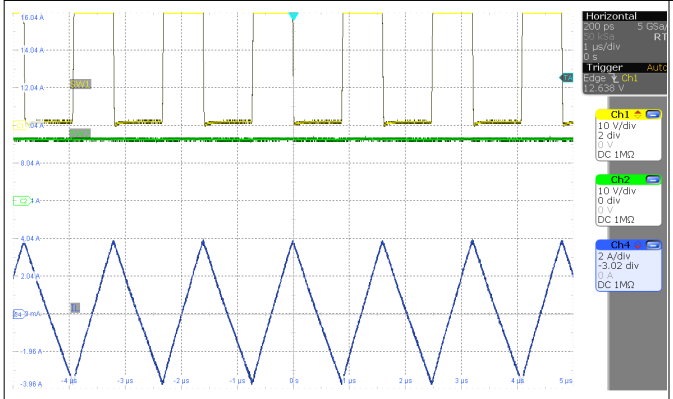


Figure 3-15. SW1, SW2, I_L (V_{IN} = 36V, I_{OUT} = 0A)

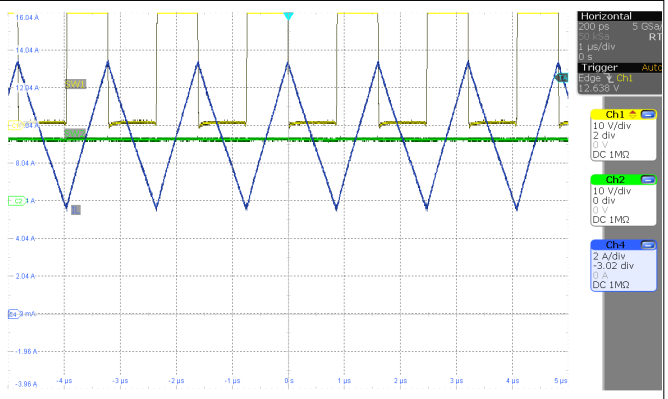


Figure 3-16. SW1, SW2, I_L (V_{IN} = 36V, I_{OUT} = 9.4A)

3.1.4 Step Load Response

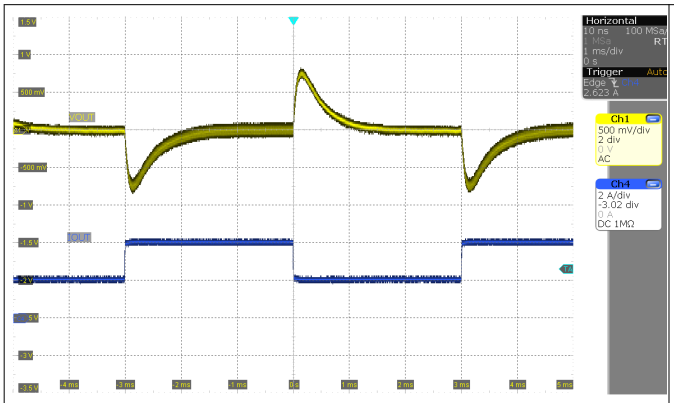


Figure 3-17. Load Step (V_{IN} = 7V, I_{OUT} = 2A–4A)

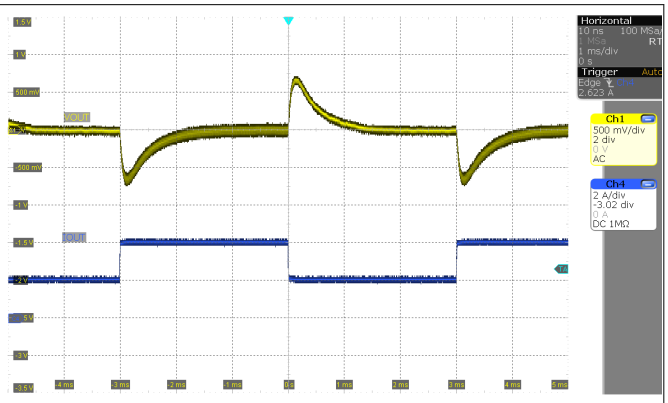


Figure 3-18. Load Step (V_{IN} = 8V, I_{OUT} = 2A–4A)

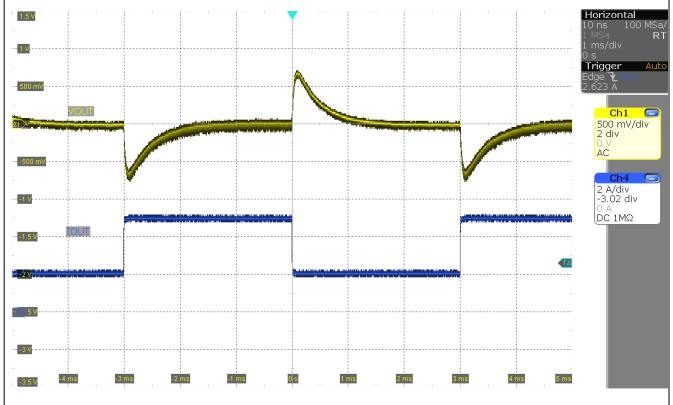


Figure 3-19. Load Step (V_{IN} = 12V, I_{OUT} = 2A–5A)

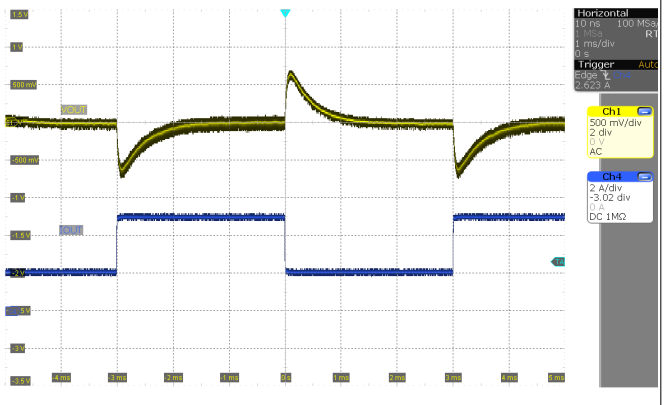


Figure 3-20. Load Step (V_{IN} = 18V, I_{OUT} = 2A–5A)

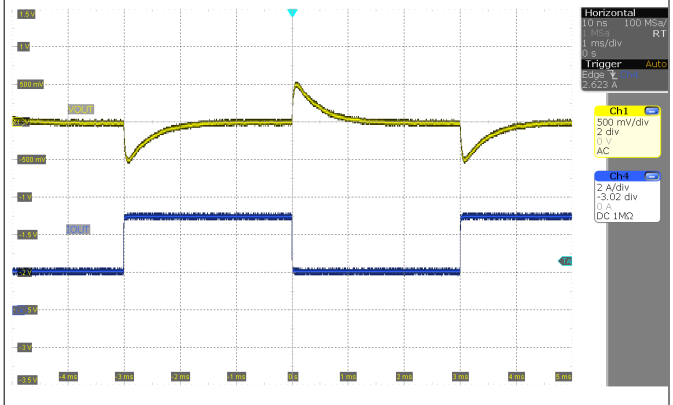


Figure 3-21. Load Step (V_{IN} = 24V, I_{OUT} = 2A–5A)

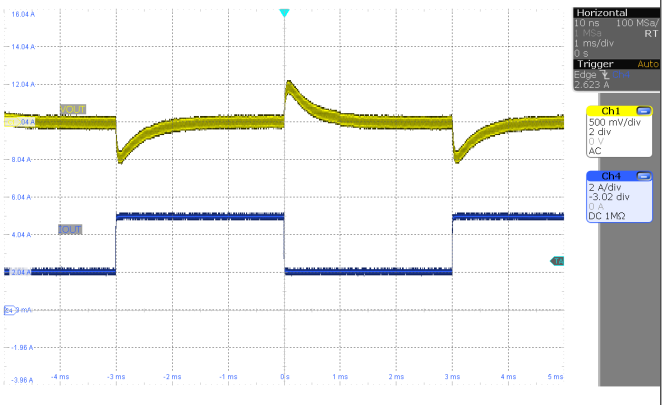


Figure 3-22. Load Step (V_{IN} = 36V, I_{OUT} = 2A–5A)

4 Hardware Design Files

4.1 Schematic

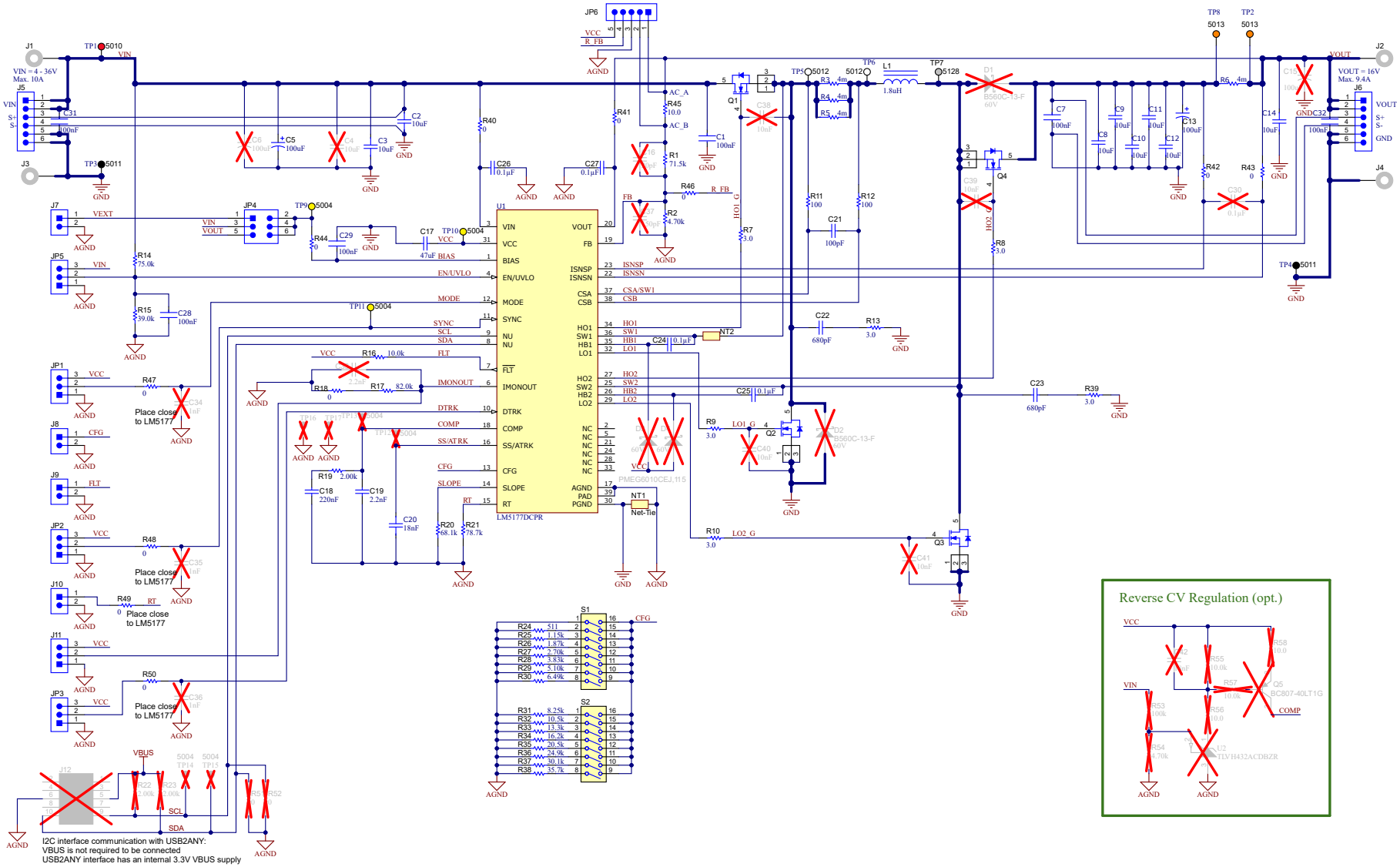


Figure 4-1. 4-Switch Buck-Boost Converter Schematic

4.2 Optional Components

Table 4-1 shows a list and function of optional components placed in the schematic

Table 4-1. 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.

4.3 Board Layout

Figure 4-2 through Figure 4-7 show the design of the LM5177EVM-HP RevC PCB.

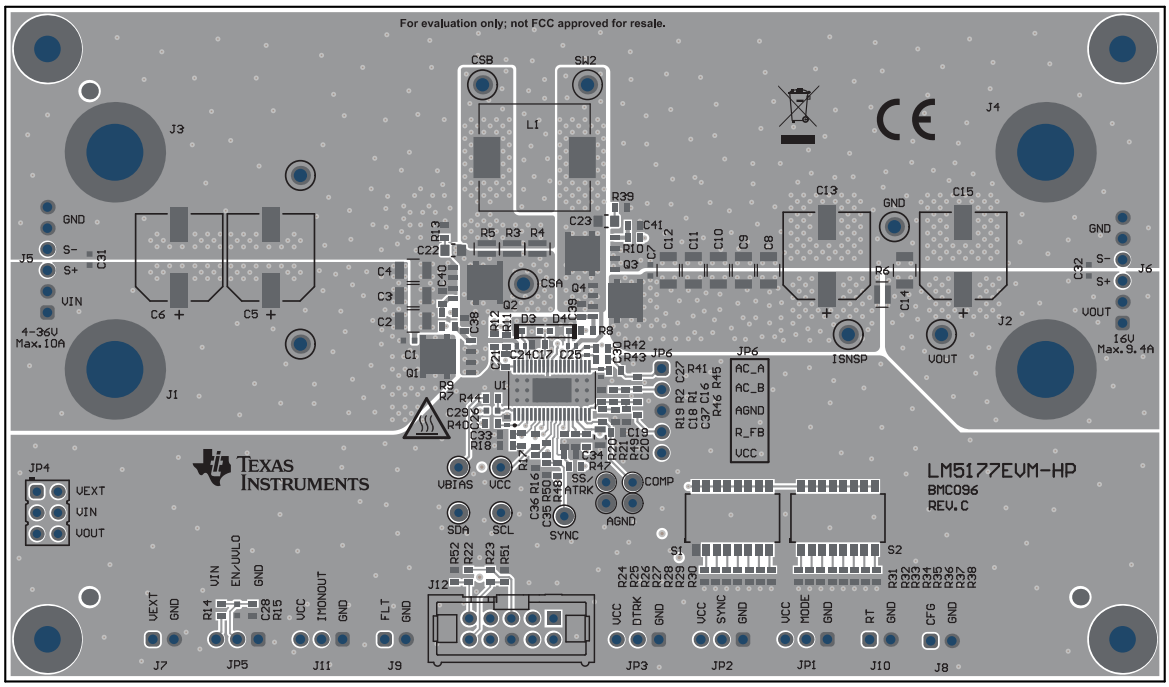


Figure 4-2. Top Silkscreen

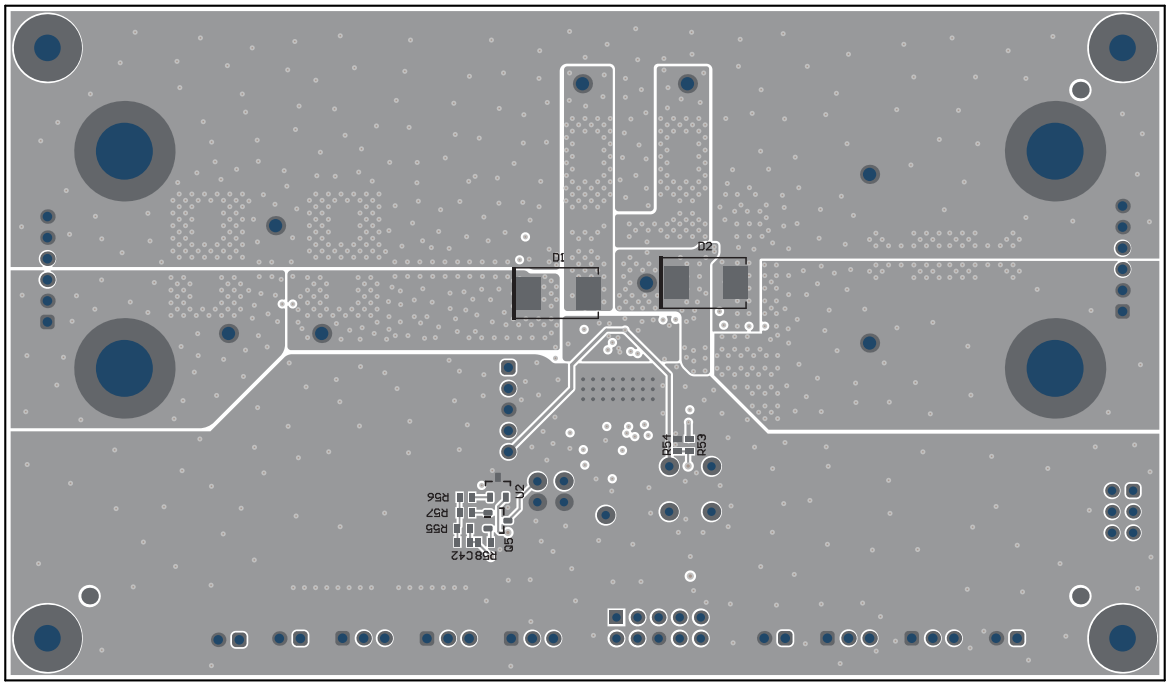


Figure 4-3. Bottom Silkscreen

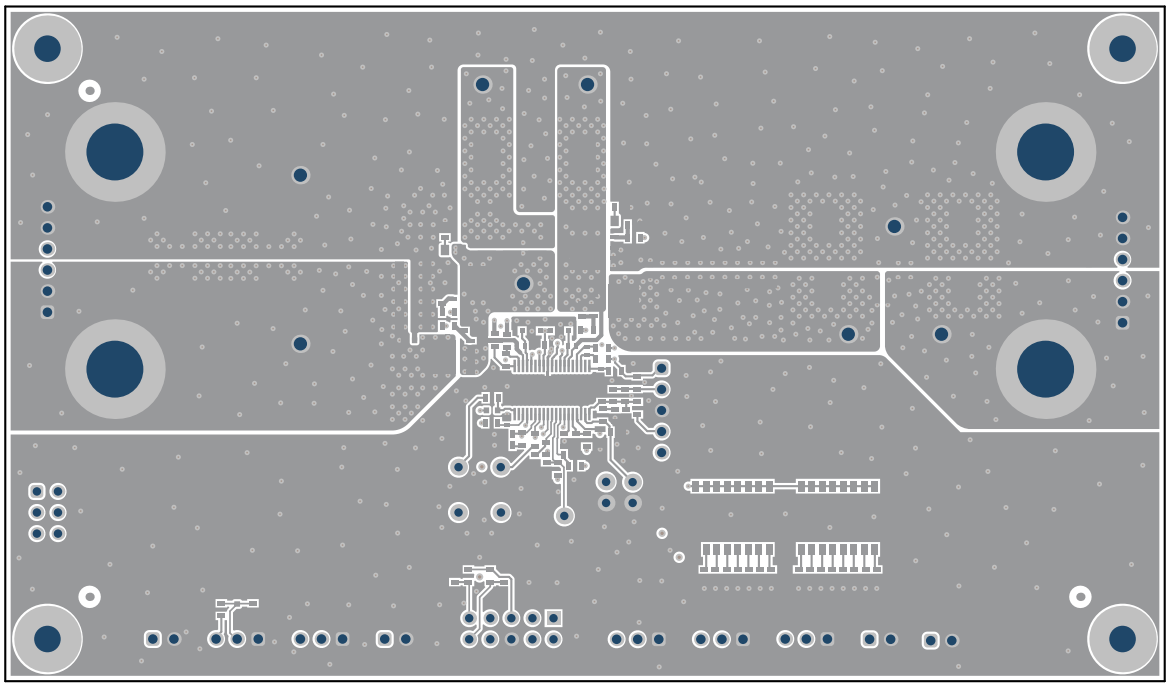


Figure 4-4. Top Layer

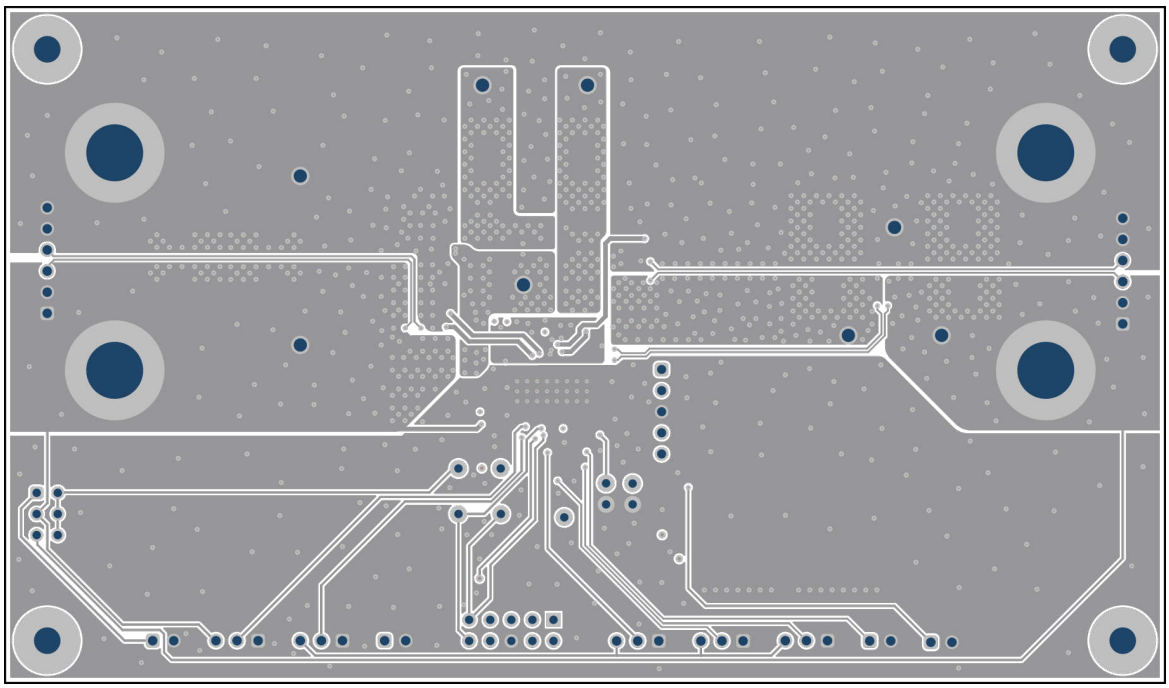


Figure 4-5. Mid-Layer 1

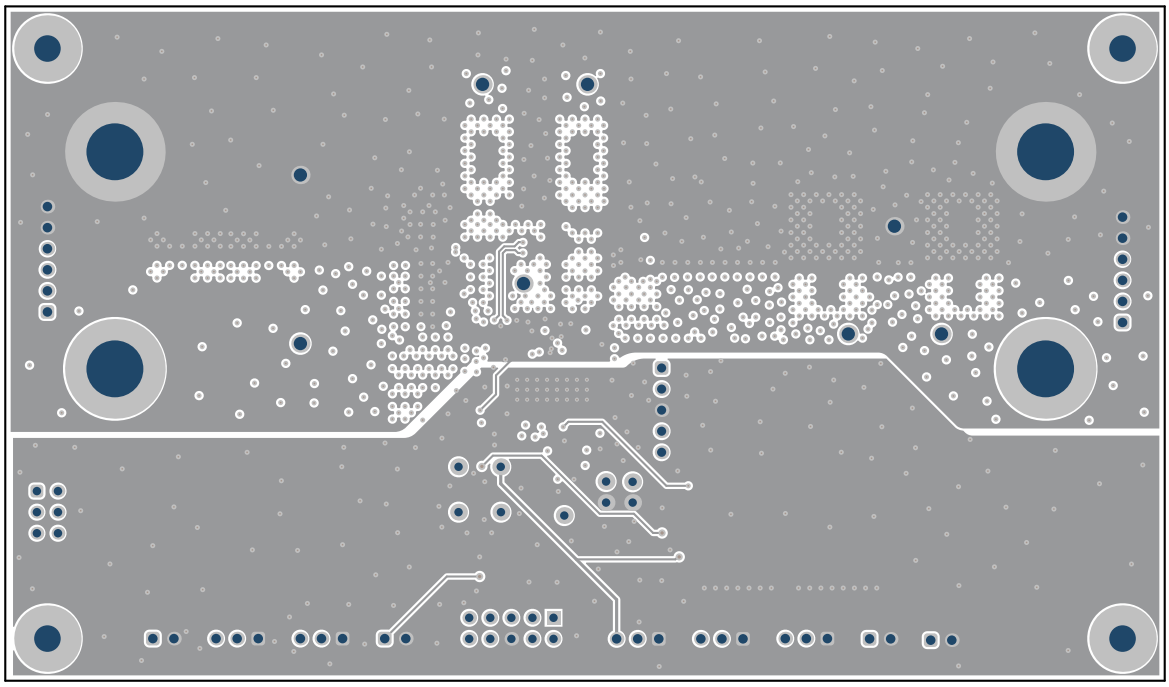


Figure 4-6. Mid-Layer 2

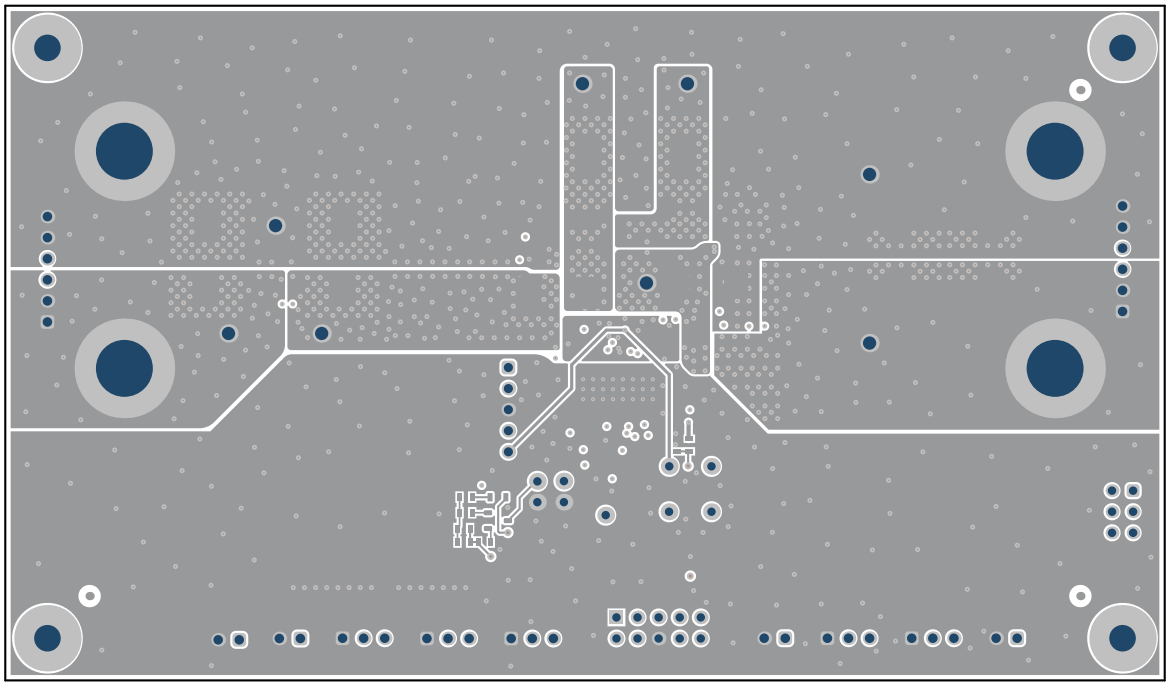


Figure 4-7. Bottom Layer

4.4 Bill of Materials

Table 4-2. Bill of Materials

Designator	Quantity	Description	Part Number	Manufacturer
C1, C7, C28, C29, C31, C32	6	0.1µF ±10% 50V 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, 100uF, 63V, +/- 20%, 0.024ohm, SMD, 2-Leads, Dia 10.5mm, Pin Spacing 8mm SMD	PCR1J101MCL1GS	Nichicon
C17	1	CAP, CERM, 47uF, 6.3V, +/- 20%, X5R, 0603	GRM188R60J476ME15D	Murata
C18	1	CAP, CERM, 0.22uF, 50V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E3X7R1H224K080AB	TDK
C19	1	CAP, CERM, 2200pF, 100V, +/- 5%, X7R, 0603	06031C222JAT2A	AVX
C20	1	Ceramic Capacitor for Automotive 18nF ±5% 50VDC C0G 0805 Embossed T/R	GCM21B5C1H183JA16L	Murata
C21	1	CAP, CERM, 100pF, 50V,+/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	GCM1885C1H101JA16J	Murata
C22, C23	2	CAP, CERM, 680pF, 50V, +/- 5%, C0G/NP0, 0805	GRM2165C1H681JA01D	Murata
C24, C25, C26, C27	4	CAP, CERM, 0.1µF, 50V,+/- 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, 2.54mm, 6x1, Gold, TH	61300611121	Wurth Elektronik
J7, J8, J9, J10	4	Header, 2.54mm, 2x1, Gold, TH	61300211121	Wurth Elektronik
J11, JP1, JP2, JP3, JP5	5	Header, 2.54mm, 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, 1.8uH, 24A, 0.0032 ohm, SMD	IHLP5050FDER1R8M01	Vishay-Dale
Q1, Q2, Q3, Q4	4	MOSFET, N-CH, 40V, 75A, 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
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

Table 4-2. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
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, 25mA, 24VDC, SMD	218-8LPST	CTS Electrocomponents
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

Table 4-2. Bill of Materials (continued)

Designator	Quantity	Description	Part Number	Manufacturer
C6, C15	0	CAP, Aluminum Polymer, 100uF, 63V, +/- 20%, 0.024 ohm, SMD, 2-Leads, Dia 10.5mm, Pin Spacing 8mm SMD	PCR1J101MCL1GS	Nichicon
C16	0	CAP, CERM, 20pF, 100V, +/- 5%, C0G/NP0, 0603	GRM1885C2A200JA01D	Murata
C30	0	CAP, CERM, 0.1µF, 50V,+/- 10%, X7R, 0402	0402BB104KW500	Passive Plus
C33	0	CAP, CERM, 2200pF, 100V, +/- 5%, X7R, 0603	06031C222JAT2A	AVX
C34, C35, C36	0	CAP, CERM, 1000pF, 100V, +/- 5%, X7R, 0603	06031C102JAT2A	AVX
C37	0	CAP, CERM, 150pF, 50V, +/- 5%, C0G/NP0, 0603	GRM1885C1H151JA01D	Murata
C38, C39, C40, C41	0	CAP, CERM, 0.01uF, 100V, +/- 10%, X7R, 0603	GRM188R72A103KA01D	Murata
C42	0	CAP, CERM, 0.018uF, 100V, +/- 10%, X7R, 0603	C0603C183K1RACTU	Kemet
D1, D2	0	Diode, Schottky, 60V, 5A, SMC	B560C-13-F	Diodes Inc.
D3, D4	0	Diode, Schottky, 60V, 1A, 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, 45V, 0.5A, AEC-Q101, SOT-23	BC807-40LT1G	ON Semiconductor
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, 129ppm / degC, 80mA, 0 to 70 degC, 3-pin SOT-23 (DBZ), Green (RoHS and no Sb/Br)	TLVH432ACDBZR	Texas Instruments

Table 4-3. 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

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

6 Revision History

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

Changes from Revision C (October 2024) to Revision D (June 2025)	Page
• Added *Current Monitor and Current Limiter Configuration* section	5
• Updated schematics in *Schematic* section to match Rev. C PCB	13

STANDARD TERMS FOR EVALUATION MODULES

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。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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.

【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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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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.

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:*

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