EVM User's Guide: LM51772EVM

LM51772 Buck-Boost Controller Evaluation Module

Description

The LM51772EVM-HP demonstrates a flexible high power buck-boost design using the LM51772. The evaluation module is configured to operate from input voltage range of 9V to 48V and produce a regulated 20V output with up to 5A load current. The EVM operates with a switching frequency of 600kHz. Most settings of the device can be easily adjusted or set through jumpers, such as: operation mode (PSM or fPWM), bias supply, and external clock synchronization.

Get Started

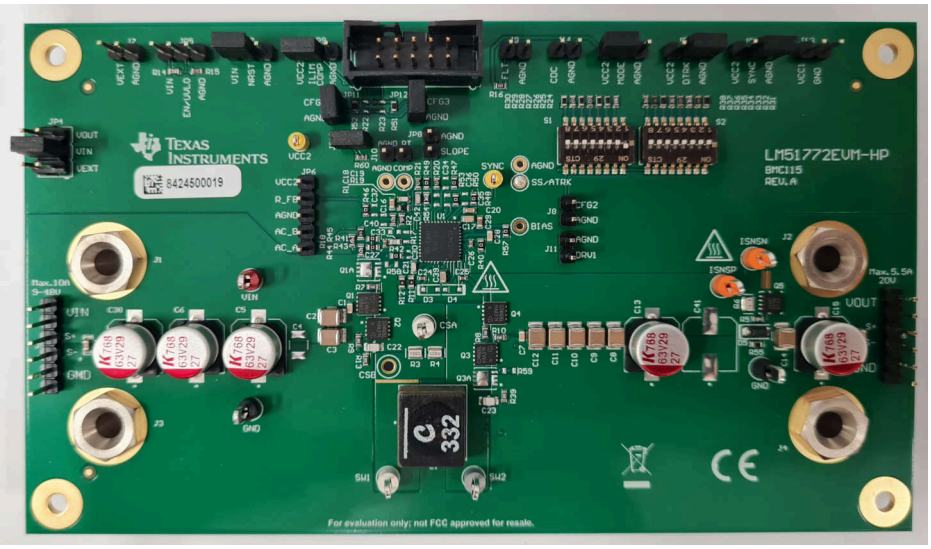
1. Connect EVM to power supply and load
2. For using the Configuration GUI and I2C operation, the USB2ANY adapter can be used
3. Install the LM51772 Configuration GUI

Features

- Wide input voltage range
- Ultra high (> 95%) peak power conversion efficiency
- Adjustable output voltage using feedback resistor divider or I2C interface
- Optional synchronization (SYNC)
- Easy configuration of current monitor or limiter
- Support for cable drop compensation
- Output disconnect support
- Programmable input undervoltage lockout (UVLO) threshold and hysteresis
- Output constant voltage (CV) and constant current (CC) options
- I2C interface with USB2ANY and GUI
- Setting of configuration resistor R_{CFG2} through DIP switches

Applications

- USB Type-C® power delivery
  - Docking station
  - PC monitor
  - Desktop PC
- Wireless charging
- Industrial PC and rugged PC
- Docking station
- Battery backup unit (BBU)
- Merchant DC/DC



1 Evaluation Module Overview

1.1 Introduction

The LM51772EVM-HP evaluation module (EVM) is designed to conveniently evaluate the performance of the LM51772 wide-VIN buck-boost controller. The LM51772 is a wide-V_{IN} four switch buck-boost controller. The device provides a regulated output voltage if the input voltage is higher, equal or lower as the adjusted output voltage. In power safe mode, the device supports a superb efficiency over the full range of the output.

Through the optional usage of the I2C interface, the device covers additional parameters for configuration and adjustments of the switch mode power supply operation.

To check the performance, the I2C interface also gives an easy access to measure the typical signals of a Buck-Boost controller.

1.2 Kit Contents

- The EVM includes one LM5177EVM-HP PCB
- EVM Disclaimer Read Me

What is Not Included

The EVM does not include the USB2ANY interface.

The USB2ANY interface can be ordered at USB2ANY interface adapter.

1.3 Specification

Table 1-1. Board Specifications

Parameter	Value
Input voltage	9.0V to 48V
Output voltage	20V
Maximum output current	5A
Default switching frequency	600kHz
Board size (four layers)	5.6 inch × 3.2 inch

1.4 Device Information

The LM51772 is a four switch Buck-Boost controller. The device provides a regulated output voltage if the input voltage is higher, equal or lower as the adjusted output voltage. In power safe mode, the device supports a superb efficiency over the full range of the output.

- Wide input range from 3.5V to 55V (EVM max. 48V)
- Output voltage 3.3V to 55V (EVM max. 48V)
- Peak current regulation scheme
- Dynamic output voltage tracking
  - Digital PWM tracking input
  - Analog tracking input
  - Via I2C interface programming
- Minimum quiescent current
  - Low shut down Iq of 3µA
  - Low operating Iq of 25µA
- Operation mode selection for high light load efficiency
  - Power save burst mode
  - µSleep power save mode
- Integrated high voltage supply LDO

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.

Note

For performing short circuit tests please close the solder joint next to Q5 (MOSFET controlled by DRV1).

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 BIAS input connection
J8	CFG2 connection
J9	FLT external connection
J10	RT external input connection
J11	DRV1 measure and external input connector
J12	I2C / USB2ANY connector
J13	VCC1 output connector
J14	CDC output connector

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 FPWM mode is enabled.	*
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 5 to Pin 6 (VOUT)	Jumper in position VOUT. VOUT (J2) is connected to the BIAS pin.	
JP5	Pin 1 to Pin 2 (GND)	Jumper in position GND (EN/UVLO pin tied GND). The LM51772 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 LM51772 is enabled.	
JP6	Pin 1 / Pin2	Connection point for loop stability measurement (Bode plot).	
	Pin 3	GND	
	Pin 4 to Pin 5	Jumper in position selects internal feedback divider.	
	Open	External Feedback divider is selected	*
JP7	Pin 1 to Pin 2 (GND)	Set nRST to GND: Disable device.	
	Pin 2 to Pin 3 (VCC)	Set nRST to VCC: Enable device.	*
JP8	Pin 1 to Pin 2	Enable I2C and set I2C Address 6A	
	Open	Remove jumper to disable I2C operation and set Slope configuration	*
JP9	Pin 1 to Pin 2 (GND)	Do not set jumper, can be used to measure ILIMCOMP signal	
	Pin 2 to PIN 3 (VCC)	ILIMCOMP connected to VCC. Disable ILIMCOMP	*
JP10	Pin 1 to Pin 2	Set jumper to enable ILIM filter for no DAC	*
	Open	Simple ILIM Filter for DAC operation is set. Complex filter can be set with populating R17 and C40.	
JP11	Pin 1 to Pin 2	Set jumper to enable config setting for no I2C configuration	*
	Open	Remove jumper of I2C operation	
JP12	Pin 1 to Pin 2	Set jumper to enable config setting for no I2C operation	*
	Open	Remove jumper for I2C operation	

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/TP9	CSB test point
TP7	SW2 test point
TP8	ISNSP test point
TP10	VCC2 test point
TP11	SYNC test point
TP12	SS/ATRK test point
TP13	COMP test point
TP14	GND
TP15	BIAS voltage test point
TP16	GND

2.1.4 Selection Switch Descriptions

2.1.4.1 S1 and S2 CFG Setting

These switches enable to set the resistor for the CFG2 pin. Details can be found in the *LM51772* data sheet.

Table 2-4. CFG2 Pin Configuration Overview

#	EN_SYNC_OUT	SYNC_IN_FALLING	VDET_EN	PCM_HYST_30
1	DISABLED	DISABLED	DISABLED	DISABLED
2	ENABLED			
3	DISABLED	ENABLED		
4	ENABLED			
5	DISABLED	DISABLED	ENABLED	
6	ENABLED			
7	DISABLED	ENABLED		
8	ENABLED			
9	DISABLED	DISABLED	DISABLED	ENABLED
10	ENABLED			
11	DISABLED	ENABLED		
12	ENABLED			
13	DISABLED	DISABLED	ENABLED	
14	ENABLED			
15	DISABLED	ENABLED		
16	ENABLED			

Note

Only one switch must be closed!

The remaining configuration inputs have been set to below setting:

- CFG1:
  - Slope Factor: 1.5
- CFG3:
  - VCC1: enabled
  - INDUCT De-rate: disabled (30%)
  - µSLEEP: enabled
  - SCALE_DT: disabled
- CFG4:
  - DRSS: disabled
  - SCP – hiccup mode: disabled
  - Negative current limit: disabled
  - Current limit: enabled

Note

The LM51772EVM-HP has been configured with disabled I2C operation with JP8 not set. The slope compensation default setting is 1.5. This can be adjusted through I2C command or by replacing R20 with the corresponding resistor.

Note

EVMs populated with PLM51772 do have Slope Compensation set to 0.875 and Inductor de-rate set to enabled via R2D.

2.1.5 I2C Operation

By default, the EVM is set to standalone mode (no I2C operation).

To configure the EVM for I2C operation change following jumper settings:

- Set JP8
- Remove JP11
- Remove JP12

If pull-ups for the I2C interface are not provided by the I2C controller, then add R22/R23.

Note

When changing the output voltage via I2C to voltages higher then 20V, limit the output power for input voltages to be:

- Higher then 20V to 70W
- Less then 20V to 45W

3 Implementation Results

3.1 Test Setup and Procedure

3.1.1 Test Setup

Figure 3-1 shows a typical test setup to evaluate the LM51772EVM-HP.

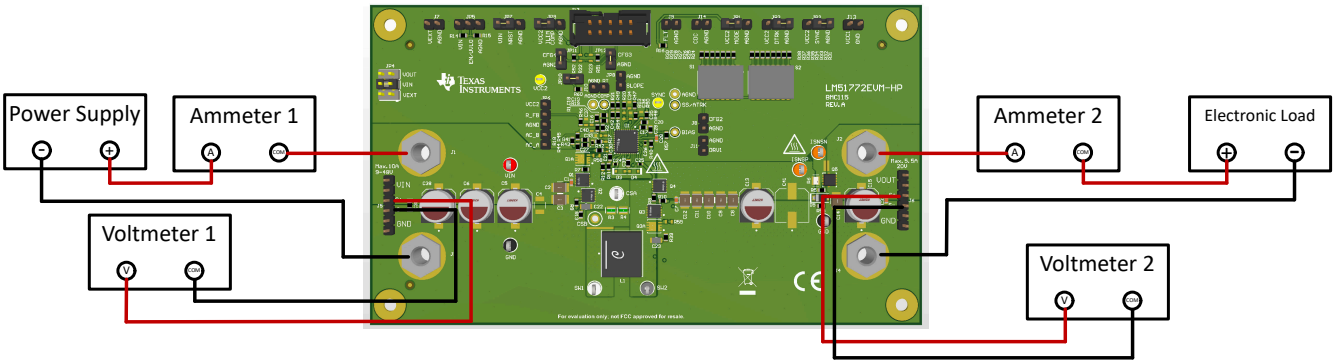


Figure 3-1. Typical EVM Connection Diagram

3.1.2 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 12V and the electronic load to 0.1A. The electronic load voltage must be in regulation with a nominal 20V output.
4. Slowly increase the load while monitoring the output voltage between J6-VOUT and J6-GND. The voltage must remain in regulation with a nominal 20V output as the load is increased up to 5A.
5. Slowly sweep the input voltage from 16V to 48V. The output voltage must remain in regulation with a nominal 20V output.
6. Slowly sweep the input voltage from 48V to 9V. The output voltage must remain in regulation with a nominal 48V output.
7. Decrease the load to 1A.
8. Decrease the input voltage down to 0V to shut down the Buck-Boost controller, and then turn off the load.

3.1.3 Precautions

3.2 Test Data and Performance Curves

3.2.1 Thermal Performance

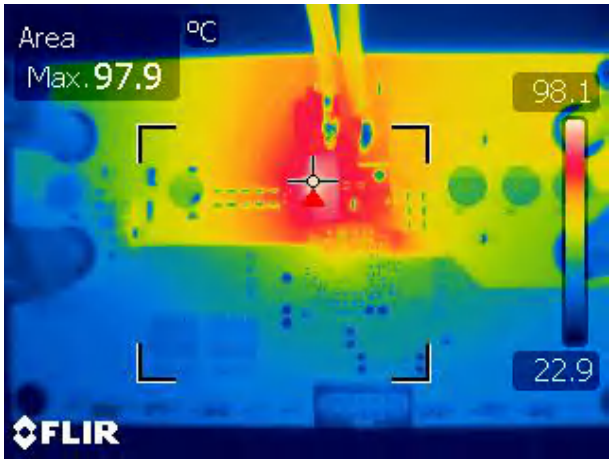


Figure 3-2. Thermal Image: V_{IN} = 9.0V, I_{OUT} = 5.0A, No Forced Air Cooling

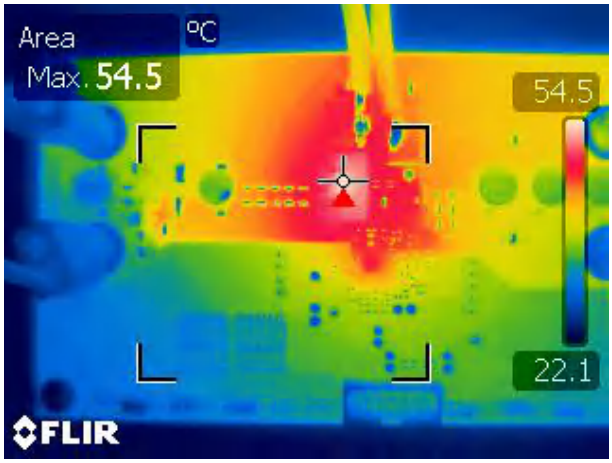


Figure 3-3. Thermal Image: V_{IN} = 16.0V, I_{OUT} = 5.0A, No Forced Air Cooling

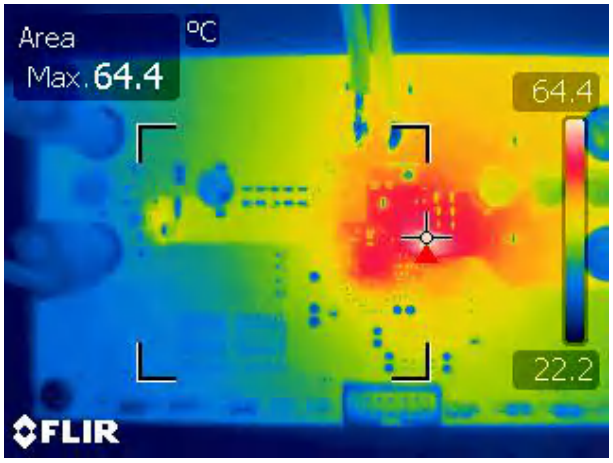


Figure 3-4. Thermal Image: V_{IN} = 24V, I_{OUT} = 5.0A, No Forced Air Cooling

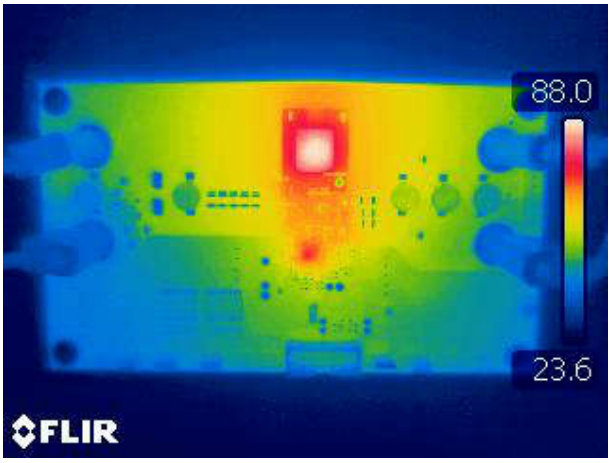


Figure 3-5. Thermal Image: V_{IN} = 48V, I_{OUT} = 5.0A, No Forced Air Cooling

3.2.2 Efficiency

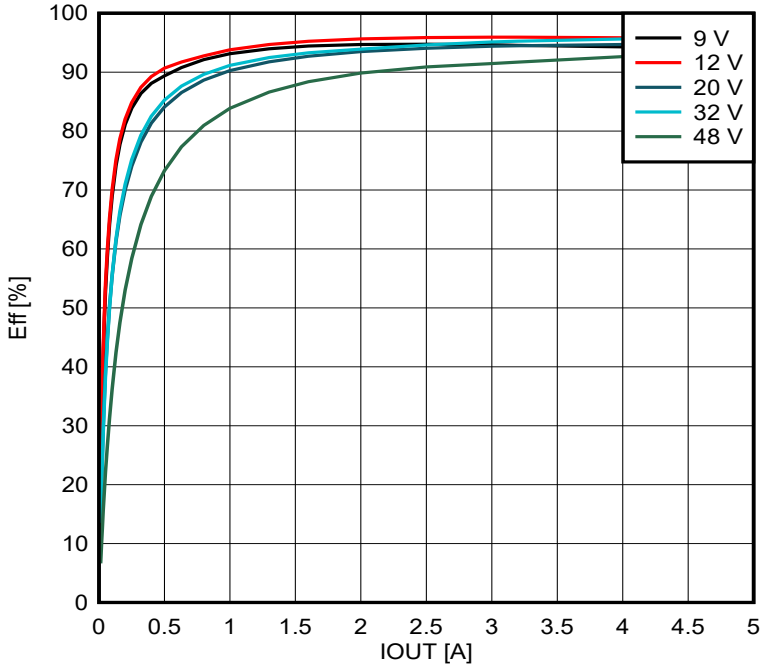


Figure 3-6. Efficiency vs. Output Current, V_O = 20V

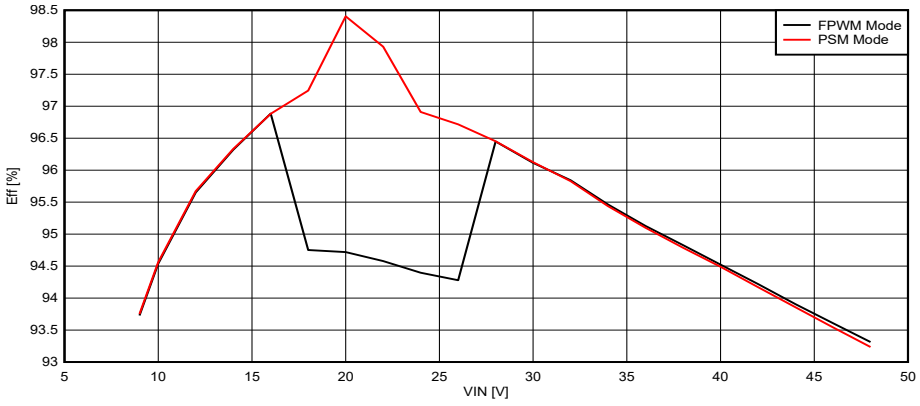


Figure 3-7. Efficiency vs. Input Voltage, V_O = 20V, I_O = 5A

3.2.3 Steady State Waveforms

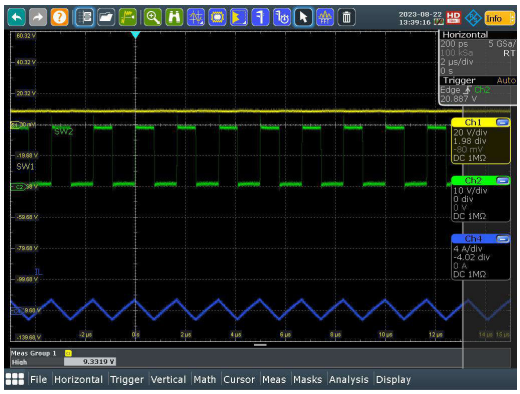


Figure 3-8. SW1, SW2, I_L (V_{IN} = 9V, I_{OUT} = 0A)

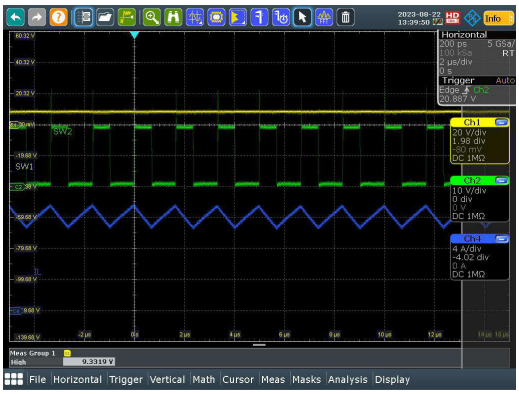


Figure 3-9. SW1, SW2, I_L (V_{IN} = 9V, I_{OUT} = 5.0A)

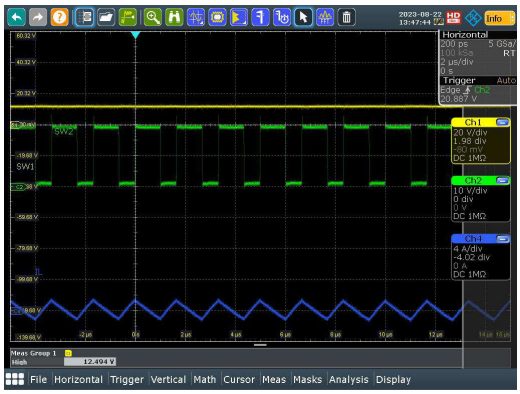


Figure 3-10. SW1, SW2, I_L (V_{IN} = 12V, I_{OUT} = 0A)

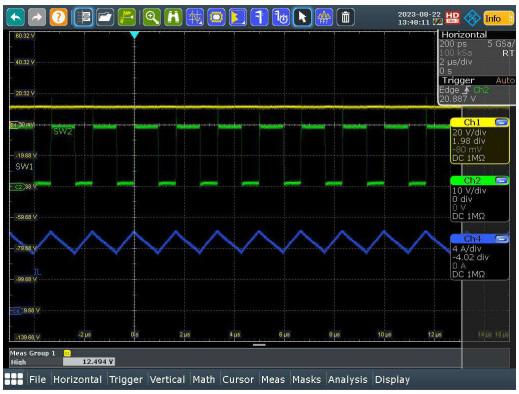


Figure 3-11. SW1, SW2, I_L (V_{IN} = 12V, I_{OUT} = 5.0A)

Figure 3-12. SW1, SW2, I_L (V_{IN} = 16V, I_{OUT} = 0A)

Figure 3-13. SW1, SW2, I_L (V_{IN} = 16V, I_{OUT} = 5.0A)

Figure 3-14. SW1, SW2, I_L (V_{IN} = 24V, I_{OUT} = 0A)

Figure 3-15. SW1, SW2, I_L (V_{IN} = 24V, I_{OUT} = 5.0A)

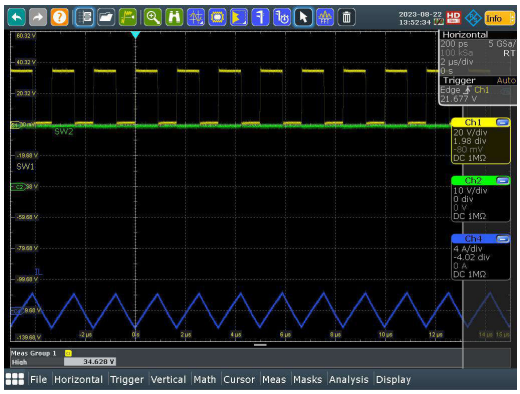


Figure 3-16. SW1, SW2, I_L (V_{IN} = 36V, I_{OUT} = 0A)

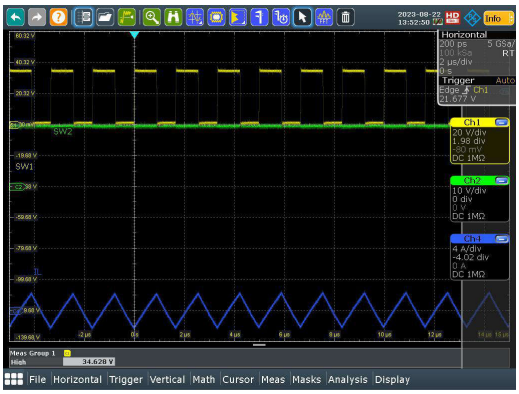


Figure 3-17. SW1, SW2, I_L (V_{IN} = 36V, I_{OUT} = 5.0A)

3.2.4 Step Load Response

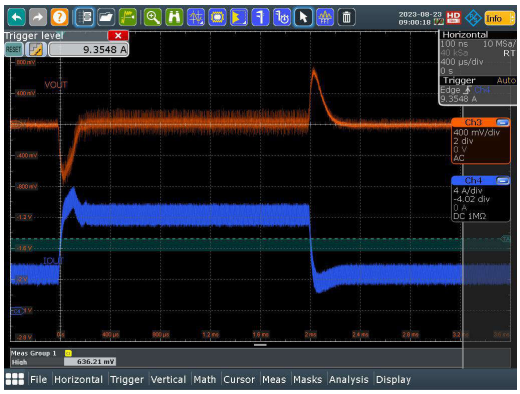


Figure 3-18. Load Step (V_{IN} = 9V, I_{OUT} = 2A – 5A)

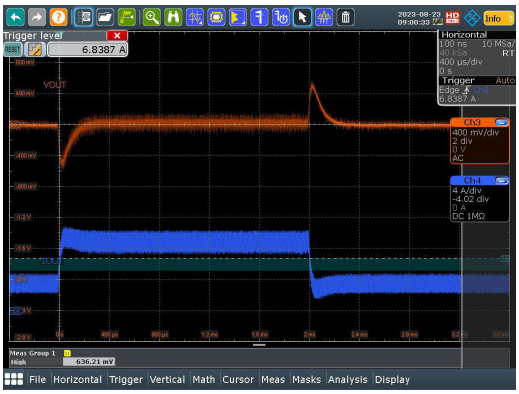


Figure 3-19. Load Step (V_{IN} = 12V, I_{OUT} = 2A – 5A)

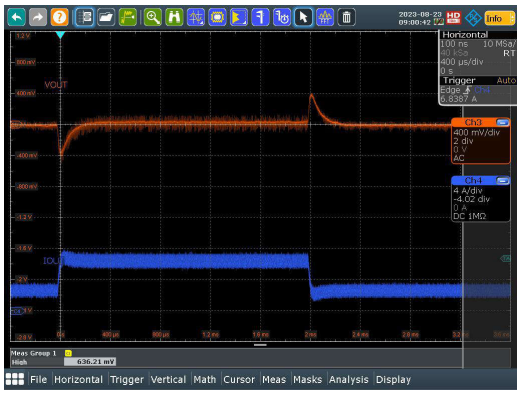


Figure 3-20. Load Step (V_{IN} = 16V, I_{OUT} = 2A – 5A)

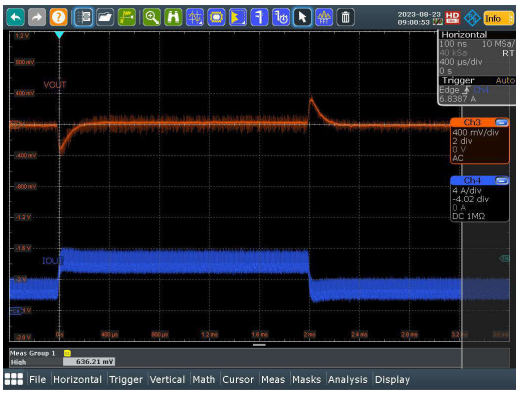


Figure 3-21. Load Step (V_{IN} = 24V, I_{OUT} = 2A – 5A)

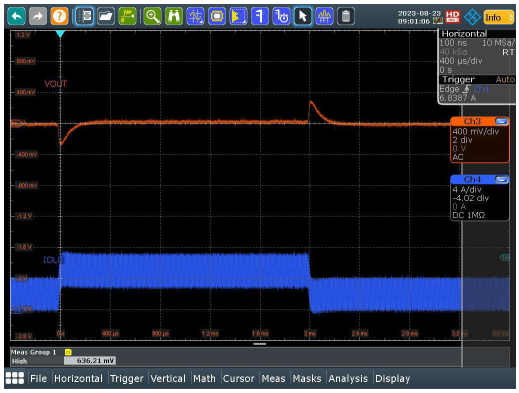


Figure 3-22. Load Step (V_{IN} = 36V, I_{OUT} = 2A – 5A)

3.2.5 AC Loop Response Curve

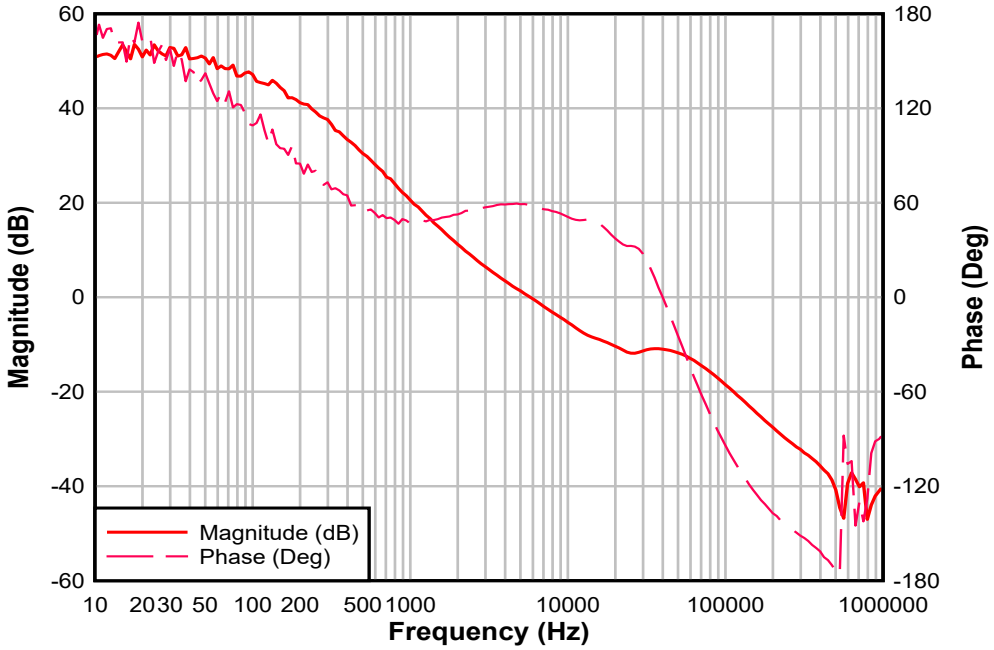


Figure 3-23. Control Loop Response, VIN = 9.0V, IOUT = 5.0A

4 Hardware Design Files

4.1 Schematic

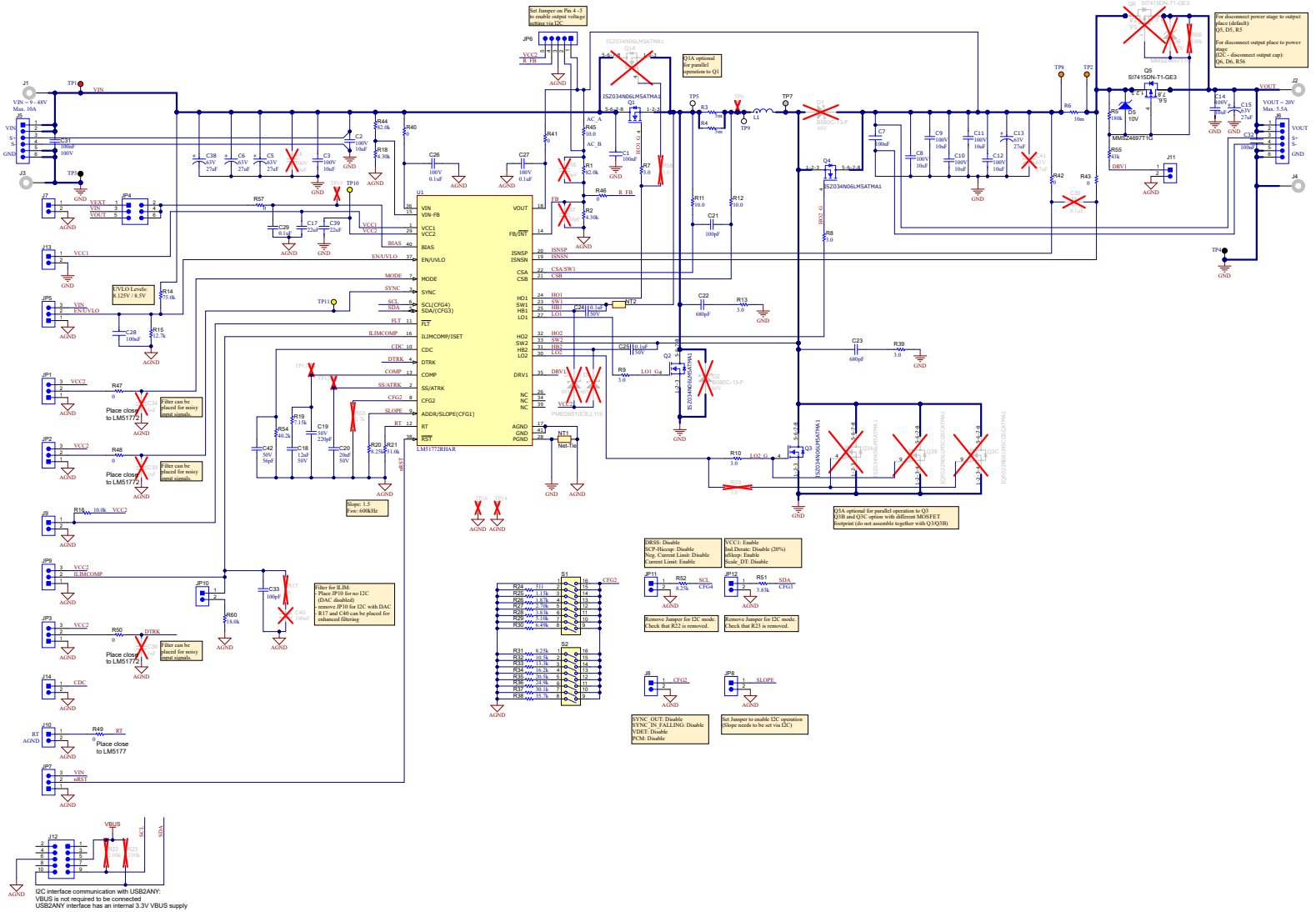


Figure 4-1. 4-Switch Buck-Boost Controller Schematic

4.2 PCB Layout

Figure 4-2 through Figure 4-7 show the design of the LM51772EVM-HP PCB.

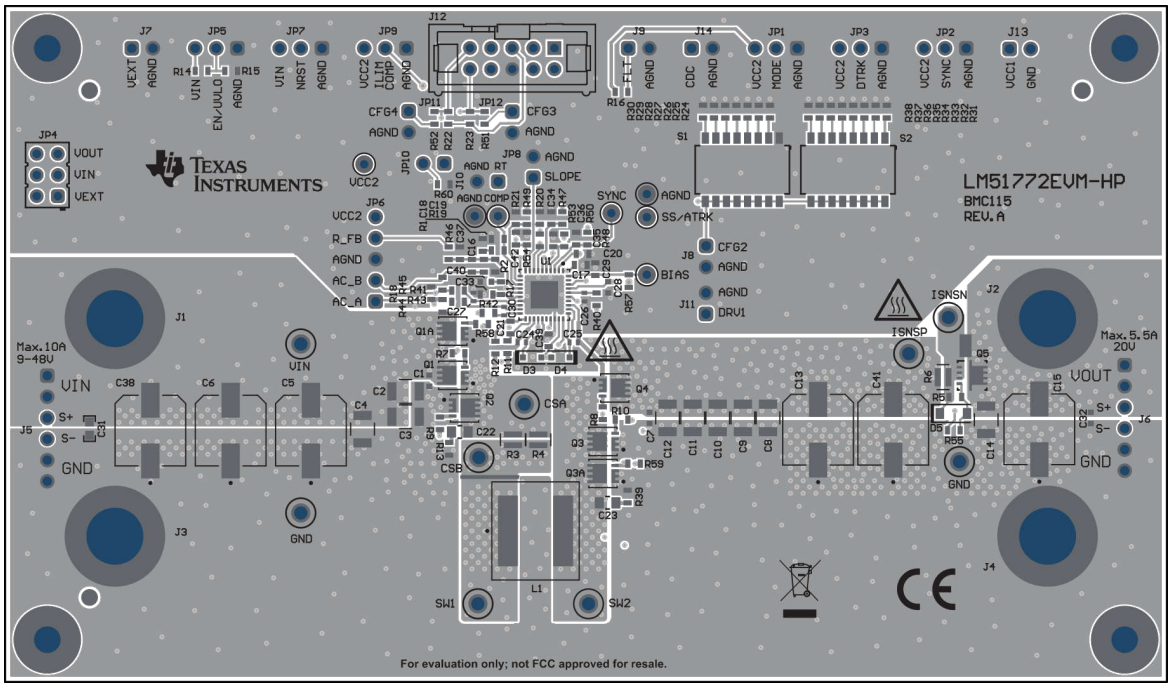


Figure 4-2. Top Silkscreen

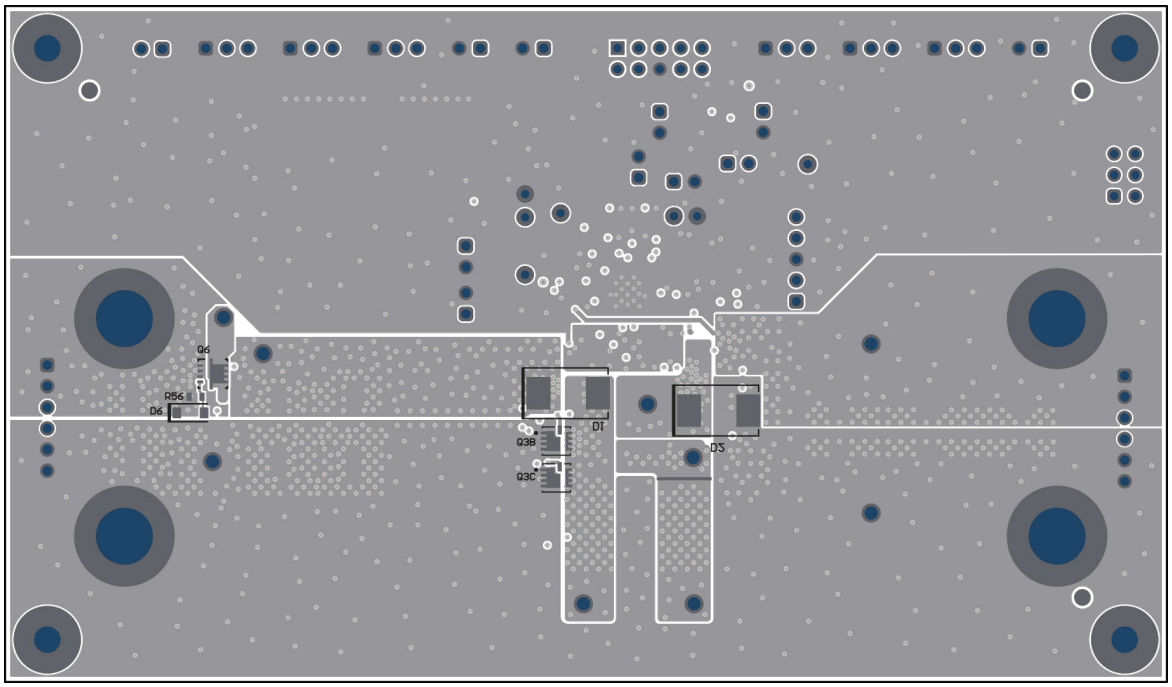


Figure 4-3. Bottom Silkscreen

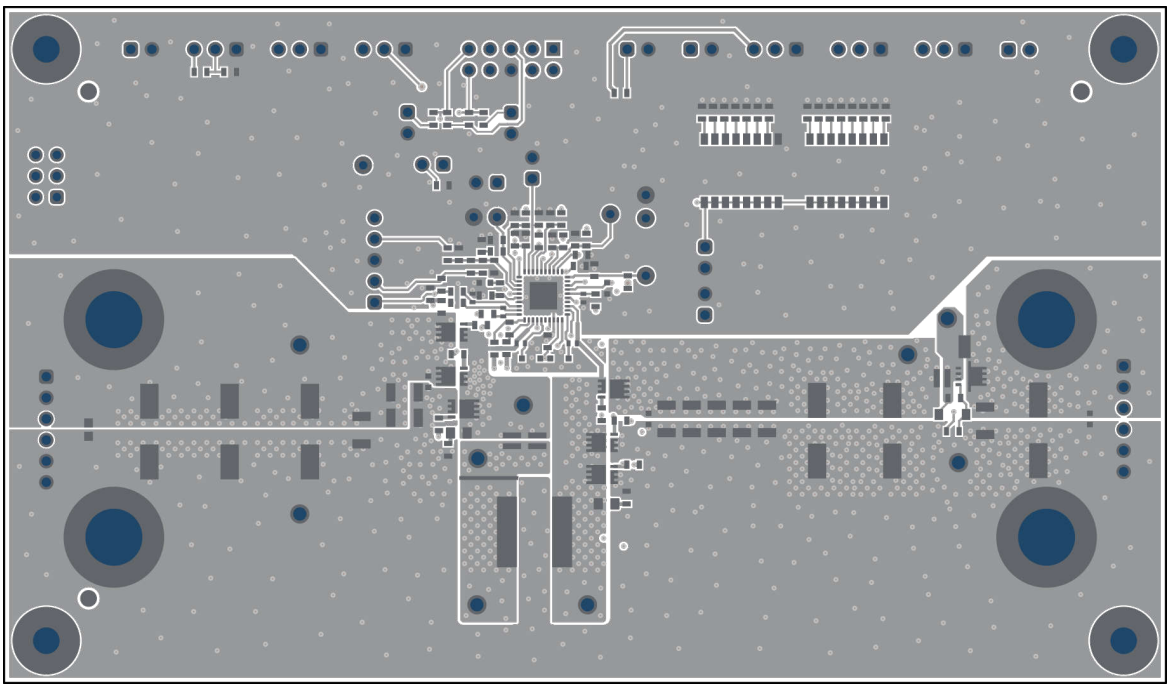


Figure 4-4. Top Layer

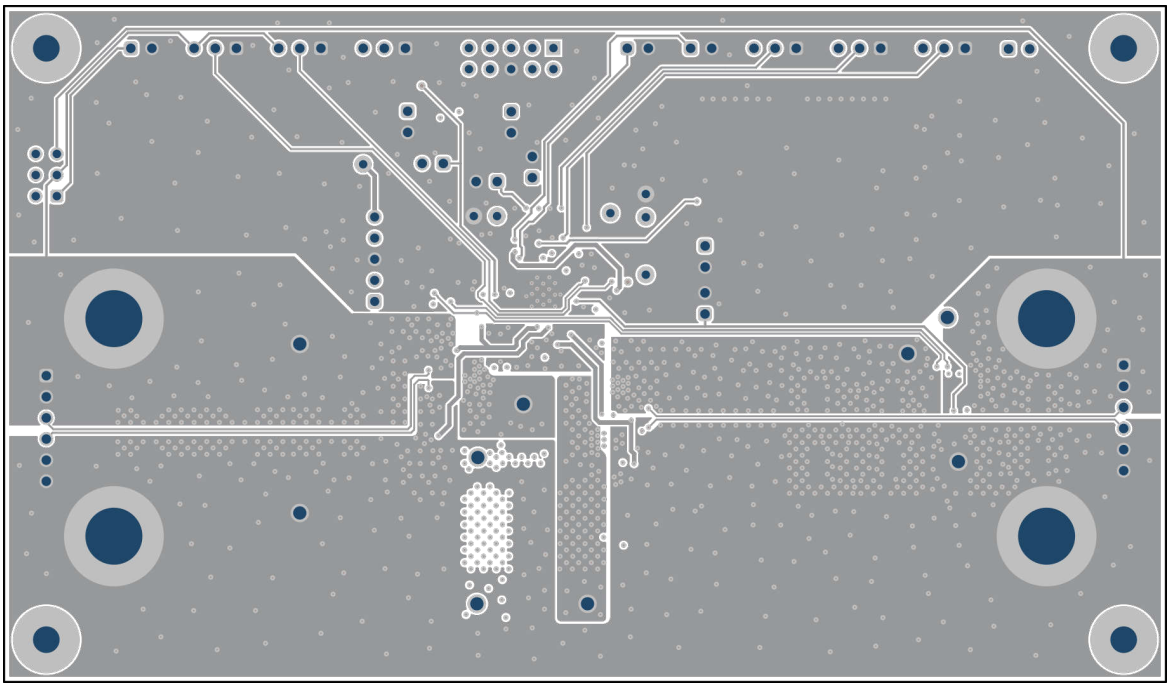


Figure 4-5. Mid-Layer 1

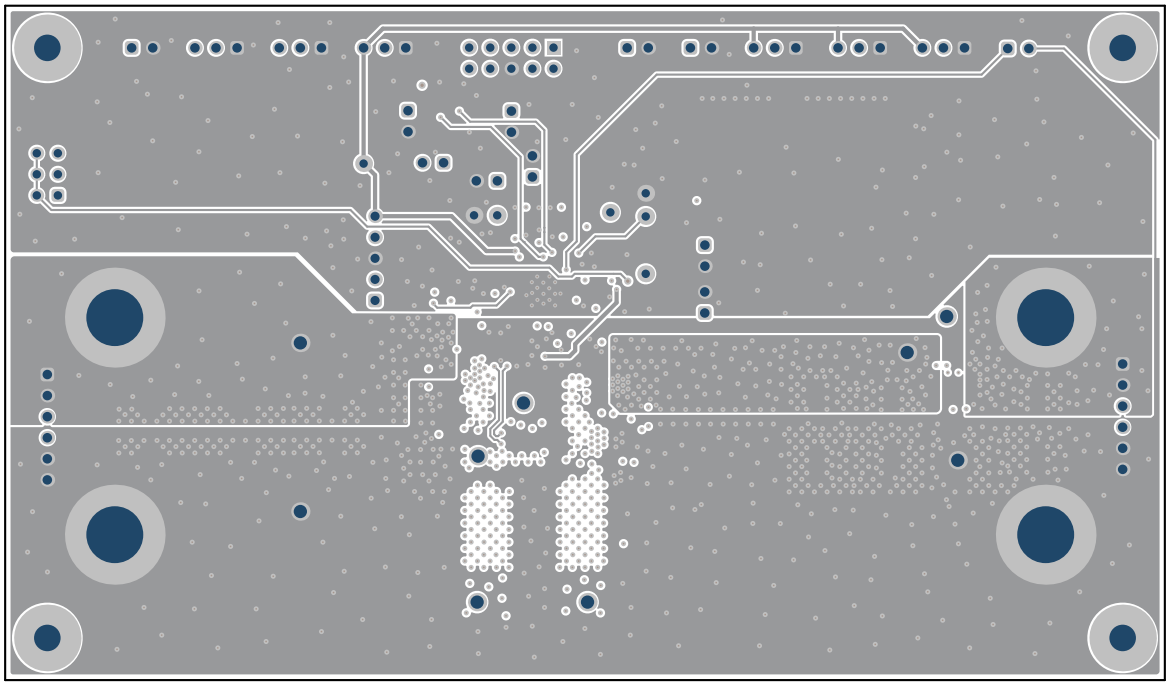


Figure 4-6. Mid-Layer 2

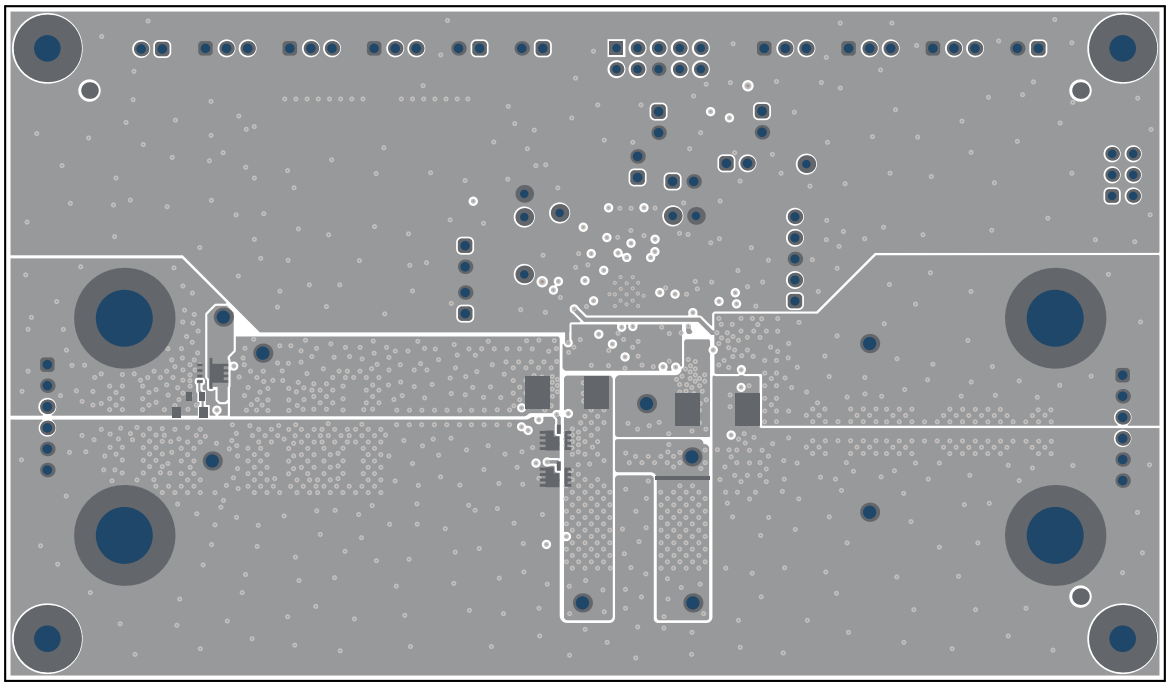


Figure 4-7. Bottom Layer

4.3 Bill of Materials

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	Part Number	Manufacturer
C1, C7, C28, C32	4	0.1µF	0.1µF ±10% 50V Ceramic Capacitor X8L 0603 (1608 Metric)	GCM188L81H104KA57D	Murata Electronics North America
C2, C3, C8, C9, C10, C11, C12, C14	8	10µF	10µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric)	C3225X7R2A106K250AC	TDK
C5, C6, C13, C15, C38	5	27µF	Cap Aluminum Polymer 27uF 63V 20% Solder Cylindrical 54m Ohm 1175mA 2000 hr 125°C T/R	A768KE276M1JLAE054	KEMET
C17, C39	2	22µF	Multi-Layer Ceramic Capacitor 22uF 10V X5R ±20% 0603 Paper T/R	GRT188R61A226ME13D	Murata
C18	1	0.012uF	CAP, CERM, 0.012µF, 50V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	C0603C123K5RACTU	Kemet
C19	1	220pF	CAP, CERM, 220pF, 50V, +/- 1%, C0G/NP0, 0603	06035A221FAT2A	AVX
C20	1	0.02uF	CAP, CERM, 0.02µF, 50V,+/- 10%, X7R, 0603	CC0603KRX7R9BB203	Yageo
C21	1	100pF	CAP, CERM, 100pF, 50V,+/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	GCM1885C1H101JA16J	MuRata
C22, C23	2	680pF	CAP, CERM, 680pF, 100V, +/- 5%, C0G/NP0, 0805	GRM2195C2A681JA01D	MuRata
C24, C25	2	0.1uF	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	GCM155R71H104KE02D	MuRata
C26, C27	2	0.1uF	CAP, CERM, 0.1uF, 100V, +/- 10%, X5R, 0402	GRM155R62A104KE14D	MuRata
C29	1	0.1uF	CAP, CERM, 0.1uF, 100V, +/- 10%, X7S, AEC-Q200 Grade 1, 0603	CGA3E3X7S2A104K080AB	TDK
C31	1	0.1uF	CAP, CERM, 0.1uF, 100V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	GCJ188R72A104KA01D	MuRata
C33	1	100pF	CAP, CERM, 100pF, 50V, +/- 1%, C0G/NP0, 0603	06035A101FAT2A	AVX
C42	1	56pF	CAP, CERM, 56pF, 50V, +/- 1%, C0G/NP0, 0603	06035A560FAT2A	AVX
D5	1	10V	Diode, Zener, 10V, 500mW, SOD-123	MMSZ4697T1G	ON Semiconductor
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, J11, J13, J14, JP8, JP10, JP11, JP12	11		Header, 2.54mm, 2x1, Gold, TH	61300211121	Wurth Elektronik

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer
J12	1		Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	N2510-6002-RB	3M
JP1, JP2, JP3, JP5, JP7, JP9	6		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	3.3uH	Shielded Power Inductors 3.3uH 22A 5.7mOhm	XGL1060-332MEC	Coilcraft
Q1, Q2, Q3, Q4	4		N-Channel 60V 19A (Ta), 112A (Tc) 2.5W (Ta), 83W (Tc) Surface Mount PG-TSDSON-8-26	ISZ034N06LM5ATMA1	Infineon
Q5	1	-60V	MOSFET, P-CH, -60 V, -3.6 A, PowerPAK 1212	SI7415DN-T1-GE3	Vishay-Siliconix
R1, R44	2	82.0k	RES, 82.0 k, 1%, 0.1 W, 0603	RC0603FR-0782KL	Yageo
R2, R18	2	4.30k	RES, 4.30 k, 1%, 0.1 W, 0603	RC0603FR-074K3L	Yageo
R3, R4	2	5m	5 mOhms ±1% 1W Chip Resistor Wide 0805 (2012 Metric), 0508 Automotive AEC-Q200, Current Sense Metal Foil	KRL2012E-M-R005-F-T5	Susumu
R5	1	180k	RES, 180 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603180KJNEA	Vishay-Dale
R6	1	10m	10 mOhms ±1% 1W Chip Resistor Wide 0805 (2012 Metric), 0508 Automotive AEC-Q200, Current Sense Metal Foil	KRL2012E-C-R010-F-T05	Susumu
R7, R8, R9, R10, R13, R39	6	3	RES, 3.0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033R00JNEA	Vishay-Dale
R11, R12	2	10	RES, 10.0, 1%, 0.25 W, AEC-Q200 Grade 0, 0603	CRCW060310R0FKEAHP	Vishay-Dale
R14	1	75.0k	RES, 75.0 k, 1%, 0.1 W, 0603	RC0603FR-0775KL	Yageo
R15	1	12.7k	RES, 12.7 k, 1%, 0.1 W, 0603	RC0603FR-0712K7L	Yageo
R16	1	10.0k	RES, 10.0 k, 0.1%, 0.1 W, 0603	RT0603BRD0710KL	Yageo America
R19	1	7.15k	RES, 7.15 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06037K15FKEA	Vishay-Dale
R29	2	5.10k	RES, 5.10 k, 1%, 0.1 W, 0603	RC0603FR-075K1L	Yageo
R21	1	51.0k	RES, 51.0 k, 1%, 0.1 W, 0603	RC0603FR-0751KL	Yageo
R24	1	511	RES, 511, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603511RFKEA	Vishay-Dale
R25	1	1.15k	RES, 1.15 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06031K15FKEA	Vishay-Dale
R26	1	1.87k	RES, 1.87 k, 1%, 0.1 W, 0603	RC0603FR-071K87L	Yageo

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer
R27	1	2.70k	RES, 2.70 k, 1%, 0.1 W, 0603	RC0603FR-072K7L	Yageo
R28, R51	1	3.83k	RES, 3.83 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033K83FKEA	Vishay-Dale
R30	2	6.49k	RES, 6.49 k, 1%, 0.1 W, 0603	RC0603FR-076K49L	Yageo
R20, R31, R52	2	8.25k	RES, 8.25 k, 1%, 0.1 W, 0603	RC0603FR-078K25L	Yageo
R32	1	10.5k	RES, 10.5 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K5FKEA	Vishay-Dale
R33	1	13.3k	RES, 13.3 k, 1%, 0.1 W, 0603	RC0603FR-0713K3L	Yageo
R34	1	16.2k	RES, 16.2 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060316K2FKEA	Vishay-Dale
R35	1	20.5k	RES, 20.5 k, 1%, 0.1 W, 0603	RC0603FR-0720K5L	Yageo
R36	1	24.9k	RES, 24.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060324K9FKEA	Vishay-Dale
R37	1	30.1k	RES, 30.1 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060330K1FKEA	Vishay-Dale
R38	1	35.7k	RES, 35.7 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060335K7FKEA	Vishay-Dale
R40, R41, R42, R43, R46, R47, R48, R49, R50, R57	10	0	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00	Stackpole Electronics Inc
R45	1	10	RES, 10.0, 1%, 0.1 W, 0603	RC0603FR-0710RL	Yageo
R54	1	40.2k	RES, 40.2 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060340K2FKEA	Vishay-Dale
R55	1	43k	RES, 43 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060343K0JNEA	Vishay-Dale
R60	1	18k	RES, 18.0 k, 1%, 0.1 W, 0603	RC0603FR-0718KL	Yageo
S1, S2	2		Switch, SPST, 8 Pos, 25mA, 24VDC, SMD	218-8LPST	CTS Electrocomponents
SH-JP1, SH-JP2, SH-JP3, SH-JP4, SH-JP7, SH-JP9, SH-JP10, SH-JP11, SH-JP12	9		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, TP9	2		Test Point, Multipurpose, White, TH	5012	Keystone Electronics
TP7	1		Test Point, Multipurpose, Grey, TH	5128	Keystone Electronics
TP10, TP11	2		Test Point, Miniature, Yellow, TH	5004	Keystone Electronics

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer
U1	1		Wide Vin 4 Switch Buck-Boost Controller with I2C interface, VQFN40	LM51772RHAR	Texas Instruments
C4	0	10µF	10µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric)	C3225X7R2A106K250AC	TDK
C16	0	20pF	CAP, CERM, 20pF, 100V, +/- 5%, C0G/NP0, 0603	GRM1885C2A200JA01D	MuRata
C30	0	0.1uF	CAP, CERM, 0.1µF, 50V,+/- 10%, X7R, 0402	0402BB104KW500	Passive Plus
C34, C35, C36	0	1000pF	CAP, CERM, 1000pF, 100V, +/- 5%, X7R, 0603	06031C102JAT2A	AVX
C37	0	150pF	CAP, CERM, 150pF, 50V, +/- 5%, C0G/NP0, 0603	GRM1885C1H151JA01D	MuRata
C40	0		0.1µF ±10% 50V Ceramic Capacitor X8L 0603 (1608 Metric)	GCM188L81H104KA57D	Murata Electronics North America
C41	0	27µF	Cap Aluminum Polymer 27uF 63V 20% Solder Cylindrical 54m Ohm 1175mA 2000 hr 125°C T/R	A768KE276M1JLAE054	KEMET
D1, D2	0	60V	Diode, Schottky, 60V, 5A, SMC	B560C-13-F	Diodes Inc.
D3, D4	0	60V	Diode, Schottky, 60V, 1A, SOD-323F	PMEG6010CEJ,115	Nexperia
D6	0	10V	Diode, Zener, 10V, 500mW, SOD-123	MMSZ4697T1G	ON Semiconductor
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial 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
Q1A, Q3A	0		N-Channel 60V 19A (Ta), 112A (Tc) 2.5W (Ta), 83W (Tc) Surface Mount PG-TSDSON-8-26	ISZ034N06LM5ATMA1	Infineon
Q3B, Q3C	0		MOSFET N-Channel 60V 24A (Ta), 151A (Tc) 2.5W (Ta), 100W (Tc) Surface Mount PG-WHTFN-9	IQE022N06LM5CGSCATMA1	Infineon Technologies
Q6	0	-60V	MOSFET, P-CH, -60 V, -3.6 A, PowerPAK 1212	SI7415DN-T1-GE3	Vishay-Siliconix
R17	0	82.0k	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00	Yageo
R22, R23	0	2.00k	RES, 2.00 k, 1%, 0.1 W, 0603	RC0603FR-072KL	Yageo
R53	0	2.7k	RES, 2.7 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06032K70JNEA	Vishay-Dale
R56	0	180k	RES, 180 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603180KJNEA	Vishay-Dale
R58, R59	0	3	RES, 3.0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06033R00JNEA	Vishay-Dale

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer
SH-JP5, SH-JP6, SH-JP8	0		Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
TP6	0		Test Point, Multipurpose, White, TH	5012	Keystone Electronics
TP12, TP13, TP15	0		Test Point, Miniature, Yellow, TH	5004	Keystone Electronics
TP14, TP16	0		Test Point, Miniature, Black, TH	5001	Keystone Electronics

Note

EVMs populated with PLM51772 have R20 set to 5.10k and R51 and 6.49k.

5 Additional Information

5.1 Trademarks

USB Type-C® is a registered trademark of USB Implementers Forum.
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 A (March 2024) to Revision B (June 2024) **Page**

- Changed values for CFG1 and CFG 3.....5
- Updated Schematic (with new values for R20 and R51.....13
- Updated *Bill of Materials* table (R20 and R51).....17

Changes from Revision * (September 2023) to Revision A (March 2024) **Page**

- Updated *Connector, Test Point, and Selection Switch Descriptions* section.....3
- Updated *Connectors* table.....3
- Updated *Test Points* table.....5
- Updated *S1 and S2 CFG Setting* section.....5
- Added *I2C Operation* section.....6
- Updated *Test Procedure* section.....7
- Updated *Efficiency* figures.....8
- Changed schematic.....13
- Updated *Bill of Materials* table.....17

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。
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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:*

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