*EVM User's Guide: LM51772Q1EVM-HP*

# *LM51772Q1 Buck-Boost Controller Evaluation Module*

## Description

The LM51772Q1EVM-HP demonstrates a flexible high power automotive buck-boost design using the LM51772Q1. The evaluation module is configured to operate from input voltage range of 9V to 30V and produce a regulated 12V output with up to 17A load current. The EVM operates with a switching frequency of 400kHz. 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

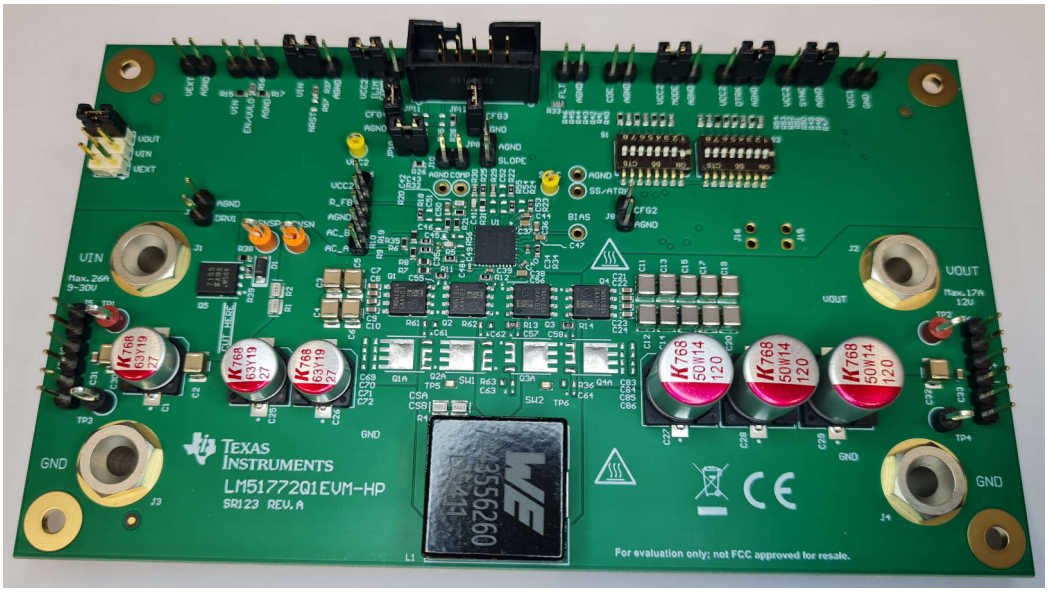
1. Connect EVM to power supply and load
2. For using the Configuration GUI and I2C operation, the USB2ANY adapter can be used
3. Install the LM51772 Configuration GUI

## 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

- Automotive ADAS domain controllers
- Automotive infotainment, digital cockpit
- Automotive sensor fusion
- USB-PD EPR (extended power range)
- Automotive energy storage, battery/super-cap backup



# 1 Evaluation Module Overview

## 1.1 Introduction

The LM51772Q1EVM-HP automotive evaluation module (EVM) is designed to conveniently evaluate the performance of the LM51772Q1 wide-VIN buck-boost controller. The LM51772Q1 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 LM51772Q1EVM-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 30V |
| Output voltage | 12V |
| Maximum output current | 17A |
| Default switching frequency | 400kHz |
| Board size (four layers) | 5.6 inch × 3.2 inch |

## 1.4 Device Information

The LM51772Q1 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 minimum 9V and maximum 30V)
- Output voltage 3.3V to 55V (EVM fixed output 12V)
- 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.

### *2.1.1 Connector Descriptions*

**Table 2-1. Connectors**

| Reference Designator | Description |
|---|---|
| J1 | Input voltage positive connection |
| J2 | Output voltage Positive connection |
| J3 | Input voltage GND connection |
| J4 | Output voltage GND connection |
| J5 | Input voltage positive and input voltage GND test point |
| J6 | Output voltage positive and output voltage GND 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 |
| J15 | Reference Voltage |
| J16 | Reverse CV Regulation Output |

### 2.1.2 Jumper Descriptions

**Table 2-2. Jumpers**

| Reference Designator | Pins | Description | Default Connection |
|---|---|---|---|
| JP1 | Pin 2 to Pin 1 (AGND) | Jumper in position AGND 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 1 or Pin3 (AGND or VCC) | Jumper in position VCC or AGND (SYNC pin tied VCC or AGND) and frequency synchronization is disabled. | * |
| | Open | Jumper removed and external clock feed in on the SYNC pin. SYNC is enabled. | |
| JP3 | Pin 2 to Pin 1 or Pin 3 (AGND or VCC) | Jumper in position AGND or VCC (DTRK pin tied AGND or VCC) 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 (AGND) | Jumper in position AGND (EN/UVLO pin tied AGND). 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 2 to 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 | AGND | |
| | Pin 4 to Pin 5 | Jumper in position selects internal feedback divider. | |
| | Open | External Feedback divider is selected | * |
| JP7 | Pin 2 to Pin 1 (AGND) | Set nRST to AGND: Disable device. | |
| | Pin 2 to Pin 3 (Vin) | Set nRST to Vin: 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 2 to PIN 3 (VCC) | ILIMCOMP connected to VCC. Disable ILIMCOMP | * |
| | Open | Do not set jumper, can be used to measure ILIMCOMP signal | |
| 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 | SW1 test point |
| TP6 | SW2 test point |
| TP7 | ISNSP test point |
| TP8 | ISNSN test point |
| TP9 | AGND |
| TP10 | VCC2 test point |
| TP11 | SYNC test point |
| TP12 | SS/ATRK test point |
| TP13 | COMP test point |
| TP14 | AGND |
| TP15 | BIAS voltage 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 CFG2 pin. Details can be found in the *LM51772Q1* 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%)
  - SCALE_DT: disabled
  - CONST_TDEAD: enabled
- CFG4:
  - DRSS: disabled
  - SCP – hiccup mode: disabled
  - Negative current limit: disabled
  - Current limit: enabled

**Note**

The LM51772Q1EVM-HP has been configured with disabled I2C operation with JP8 not set. The slope compensation can be adjusted through I2C command or by replacing R20 with the corresponding resistor, its default setting is 1.5.

### *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 the 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**

This EVM is optimized for $V_{in}$= 9V - 30V, $V_{out}$ = 12V, and $I_{out, max}$ = 17A. When adjusting the output voltage via I²C to values higher or lower than 12V with $V_{in}$ = 9V, additional optimization is required. However, the output voltage and power need to be limited to:

- $V_{out, max}$ = 30V at $P_{out}$ = 150W ($I_{out, max}$ = 5A )
- $V_{out, nom}$ = 12V at $P_{out}$ = 200W ($I_{out, max}$ = 17A)
- $V_{out, min}$ = 3.3V at $P_{out}$ = 82W ($I_{out, max}$ = 25A )

**Note**

Do not set the input voltage below 9V, while changing the output voltage beyond 12V via I²C, as the EVM is not optimized for these values.

**Note**

When using I²C do not set the output voltage above 32V because the output capacitors used for the EVM are only rated for 35V.

# 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 LM51772Q1EVM-HP.

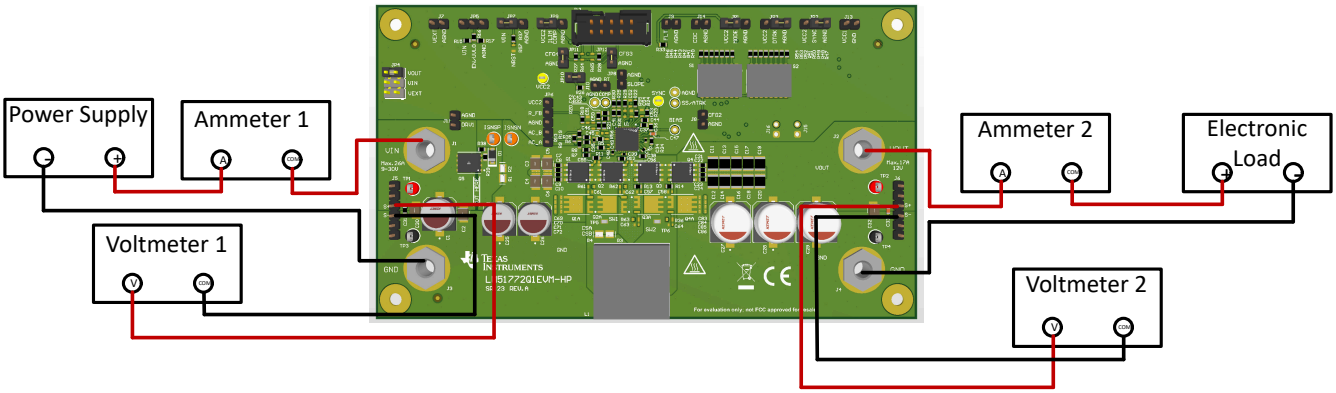



**Figure 3-1. Typical EVM Connection Diagram**

### *3.1.2 Test Procedure*

1. Set the power supply current limit to 35A. 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 9V and the electronic load to 0.1A. The electronic load voltage must be in regulation with a nominal 12V 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 12V output as the load is increased up to 17A.
5. Slowly sweep the input voltage from 9V to 30V. The output voltage must remain in regulation with a nominal 12V output.
6. Slowly sweep the input voltage from 30V to 9V. The output voltage must remain in regulation with a nominal 12V 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.

## 3.2 Test Data and Performance Curves

### *3.2.1 Thermal Performance*

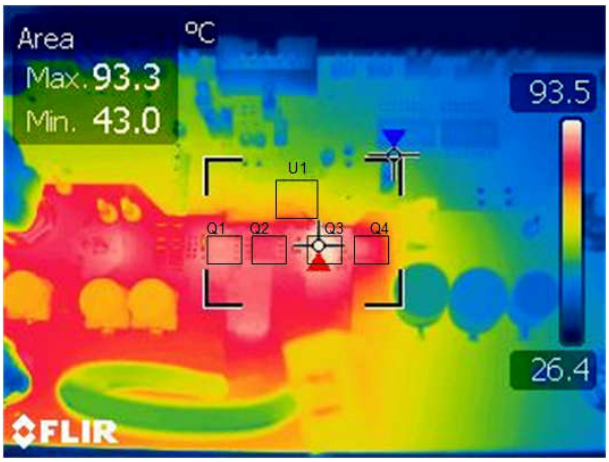



**Figure 3-2. Thermal Image: $V_{IN}$ = 9V, $I_{OUT}$ = 17A, No Forced Air Cooling**

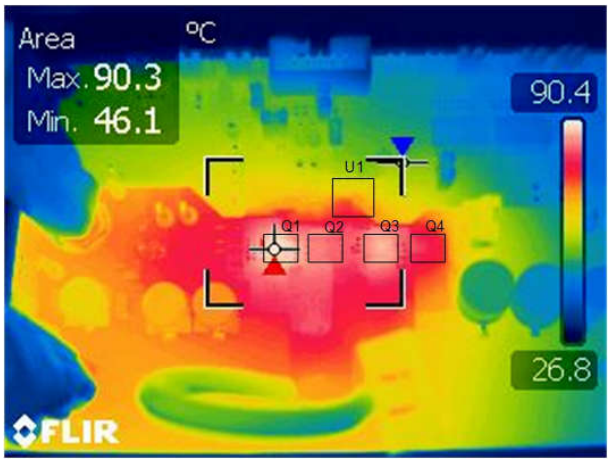



**Figure 3-3. Thermal Image: $V_{IN}$ = 12V, $I_{OUT}$ = 17A, No Forced Air Cooling**

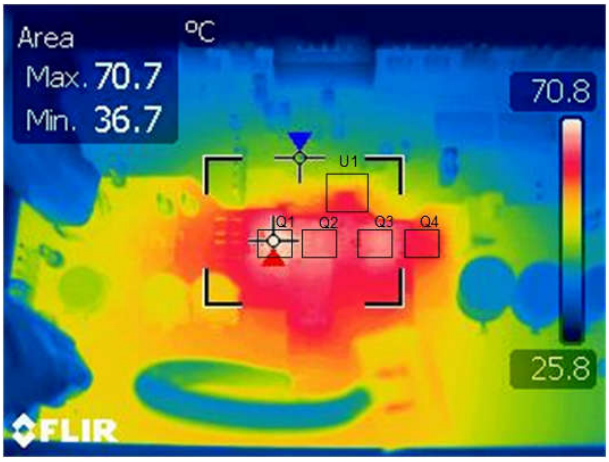



**Figure 3-4. Thermal Image: $V_{IN}$ = 16V, $I_{OUT}$ = 17A, No Forced Air Cooling**

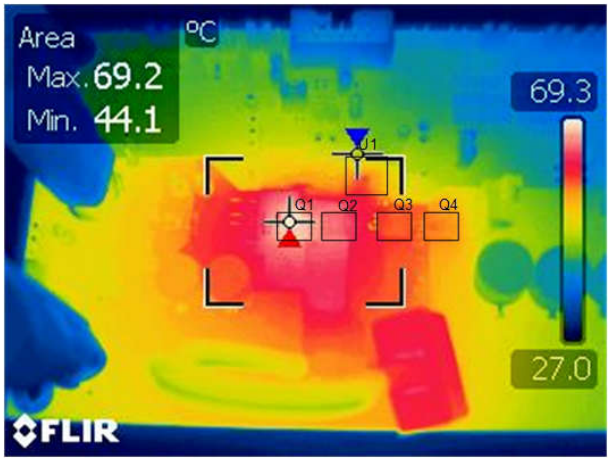



**Figure 3-5. Thermal Image: $V_{IN}$ = 20V, $I_{OUT}$ = 17A, No Forced Air Cooling**

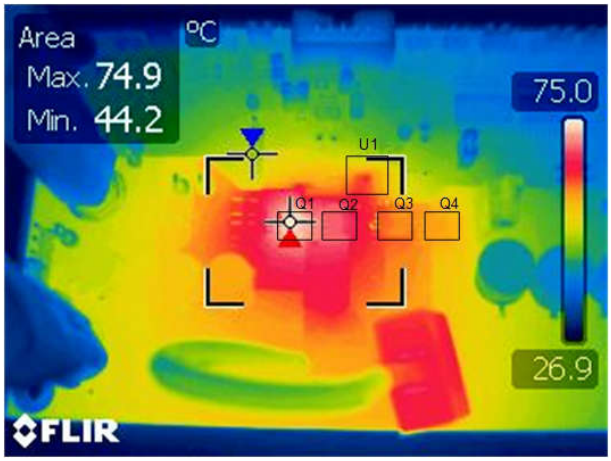



**Figure 3-6. Thermal Image: $V_{IN}$ = 30V, $I_{OUT}$ = 17A, No Forced Air Cooling**

### 3.2.2 Efficiency

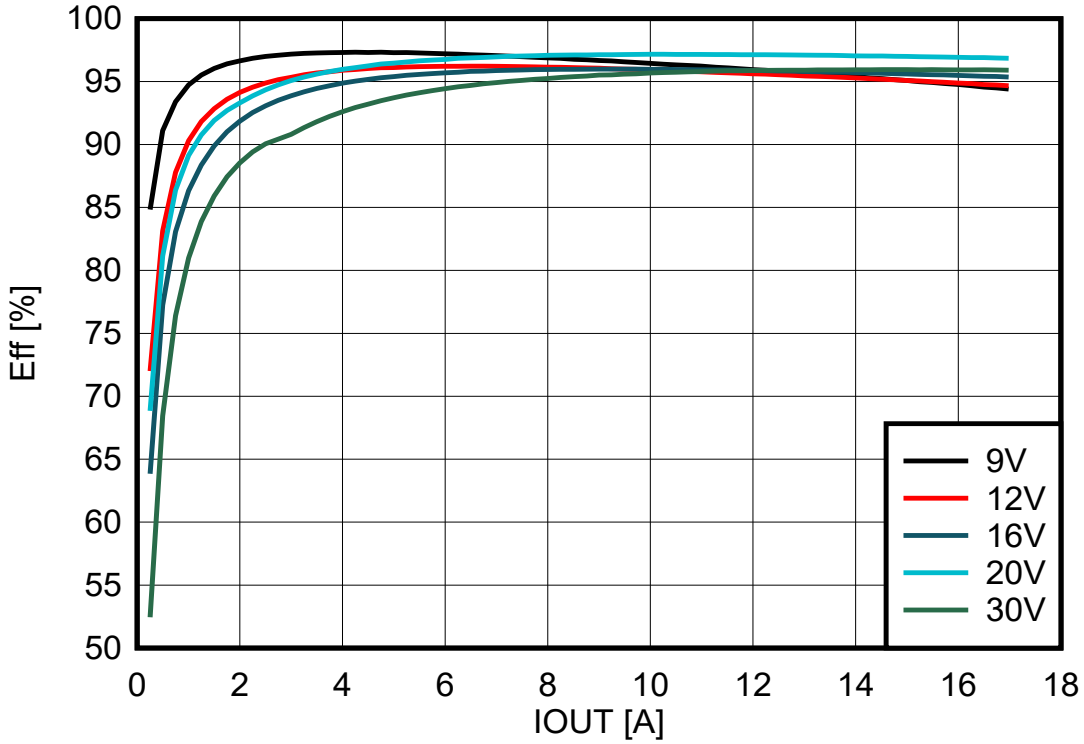



**Figure 3-7. Efficiency vs. Output Current, $V_O$ = 12V**

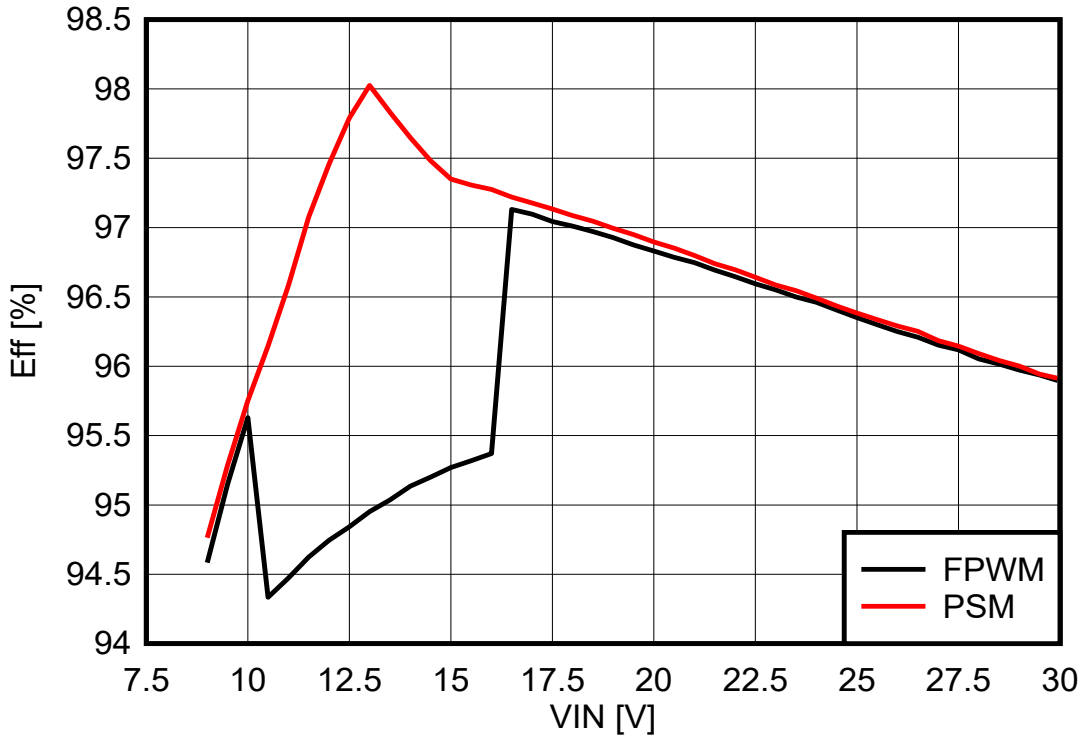



**Figure 3-8. Efficiency vs. Input Voltage, $V_O$ = 12V, $I_O$ = 17A**

### 3.2.3 Steady State Waveforms

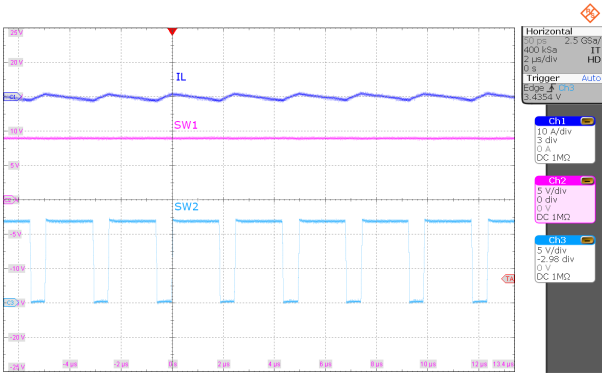



Figure 3-9. SW1, SW2, $I_L$ ($V_{IN}$ = 9V, $I_{OUT}$ = 0A)

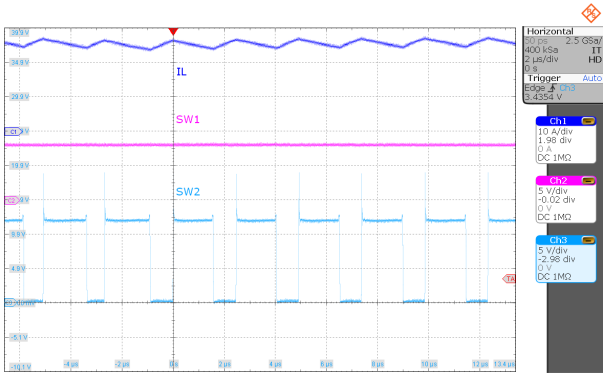



Figure 3-10. SW1, SW2, $I_L$ ($V_{IN}$ = 9V, $I_{OUT}$ = 17A)

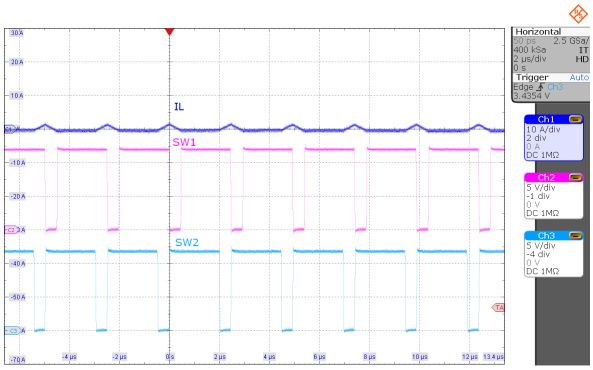



Figure 3-11. SW1, SW2, $I_L$ ($V_{IN}$ = 12V, $I_{OUT}$ = 0A)

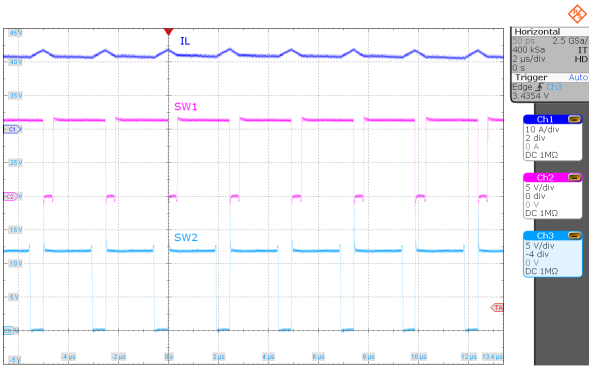



Figure 3-12. SW1, SW2, $I_L$ ($V_{IN}$ = 12V, $I_{OUT}$ = 17A)

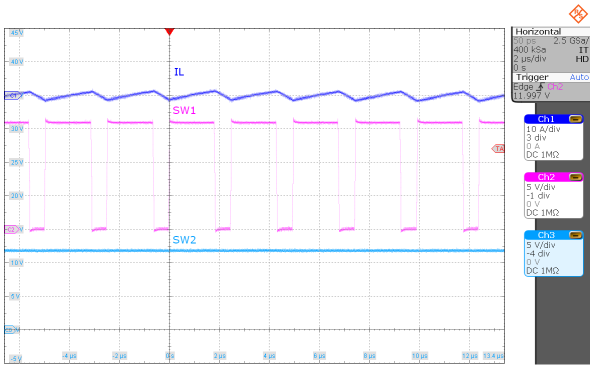



Figure 3-13. SW1, SW2, $I_L$ ($V_{IN}$ = 16V, $I_{OUT}$ = 0A)

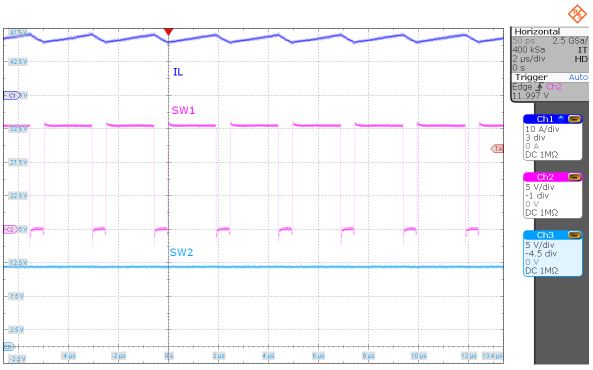



Figure 3-14. SW1, SW2, $I_L$ ($V_{IN}$ = 16V, $I_{OUT}$ = 17A)

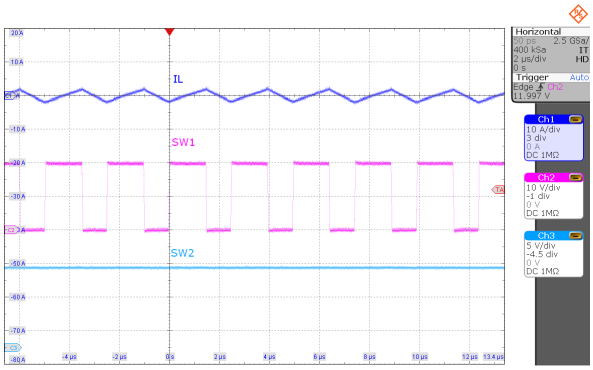



Figure 3-15. SW1, SW2, $I_L$ ($V_{IN}$ = 20V, $I_{OUT}$ = 0A)

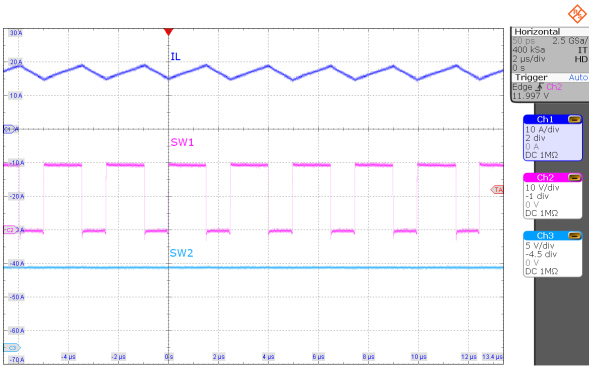



Figure 3-16. SW1, SW2, $I_L$ ($V_{IN}$ = 20V, $I_{OUT}$ = 17A)

### 3.2.3 Steady State Waveforms (continued)

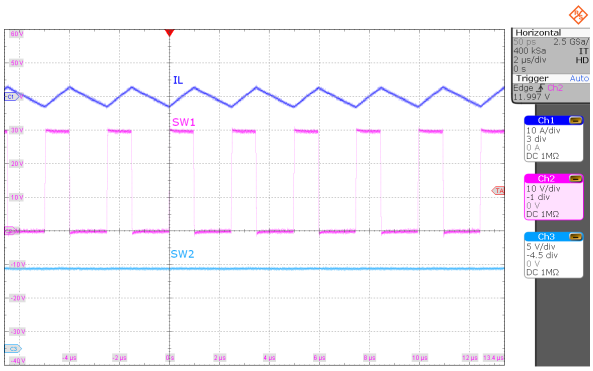



Figure 3-17. SW1, SW2, $I_L$ ($V_{IN}$ = 30V, $I_{OUT}$ = 0A)

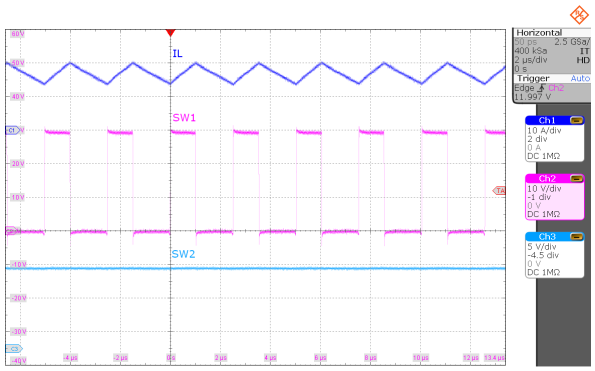



Figure 3-18. SW1, SW2, $I_L$ ($V_{IN}$ = 30V, $I_{OUT}$ = 17A)

### 3.2.4 Step Load Response

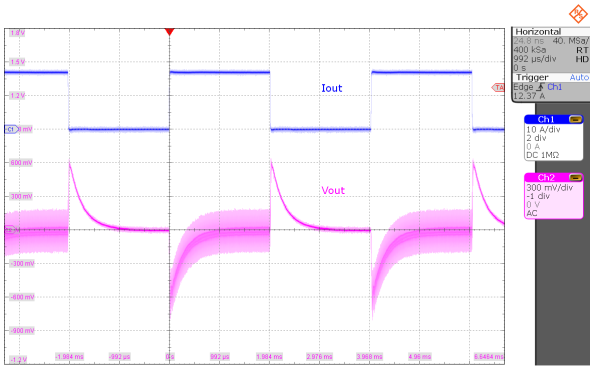



**Figure 3-19. Load Step ($V_{IN}$ = 9V, $I_{OUT}$ = 0A – 17A)**

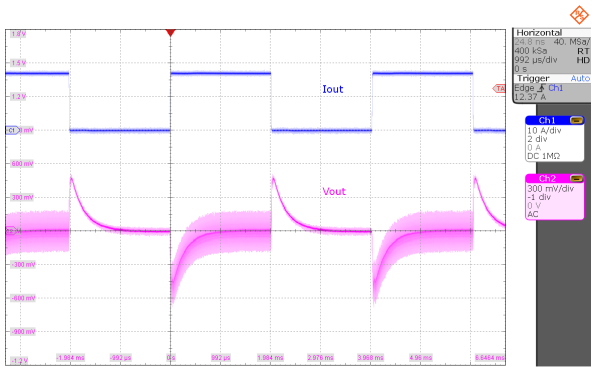



**Figure 3-20. Load Step ($V_{IN}$ = 12V, $I_{OUT}$ = 0A – 17A)**

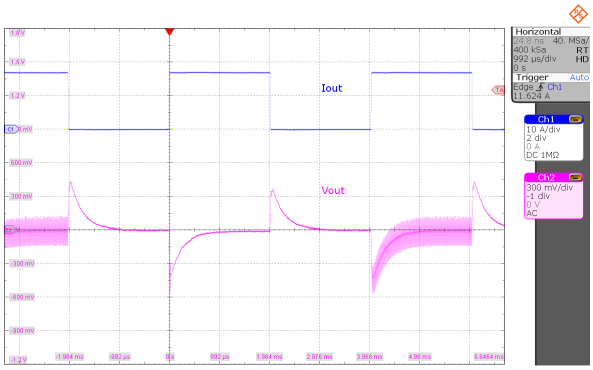



**Figure 3-21. Load Step ($V_{IN}$ = 16V, $I_{OUT}$ = 0A – 17A)**

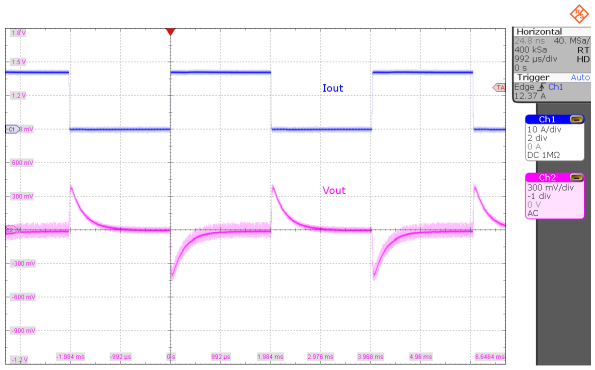



**Figure 3-22. Load Step ($V_{IN}$ = 20V, $I_{OUT}$ = 0A – 17A)**

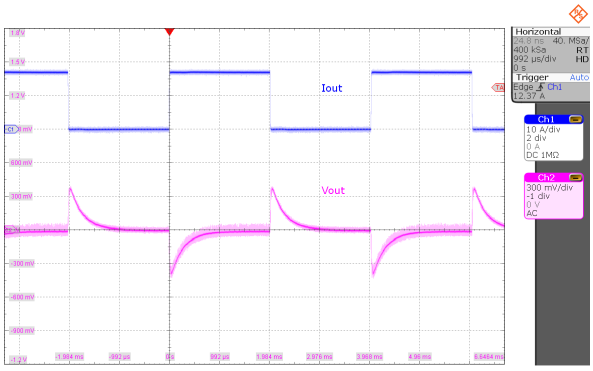



**Figure 3-23. Load Step ($V_{IN}$ = 30V, $I_{OUT}$ = 0A – 17A)**

### 3.2.5 Peak Current Limit

The EVM have a peak inductor current limit of 30A.

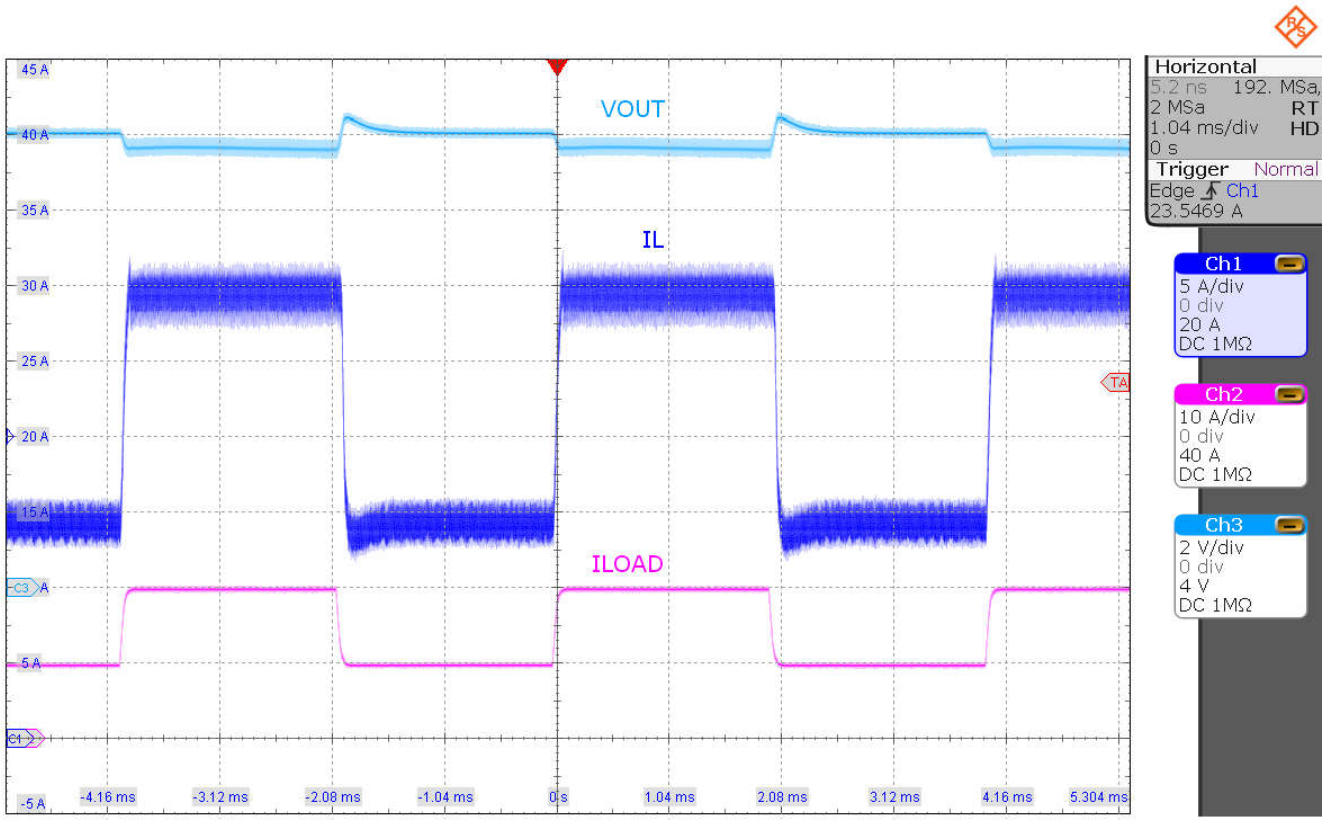



**Figure 3-24. Peak Current limit at 30A, Load Step (Vin=9V, Iout = 10A - 20A)**

### 3.2.6 AC Loop Response Curve

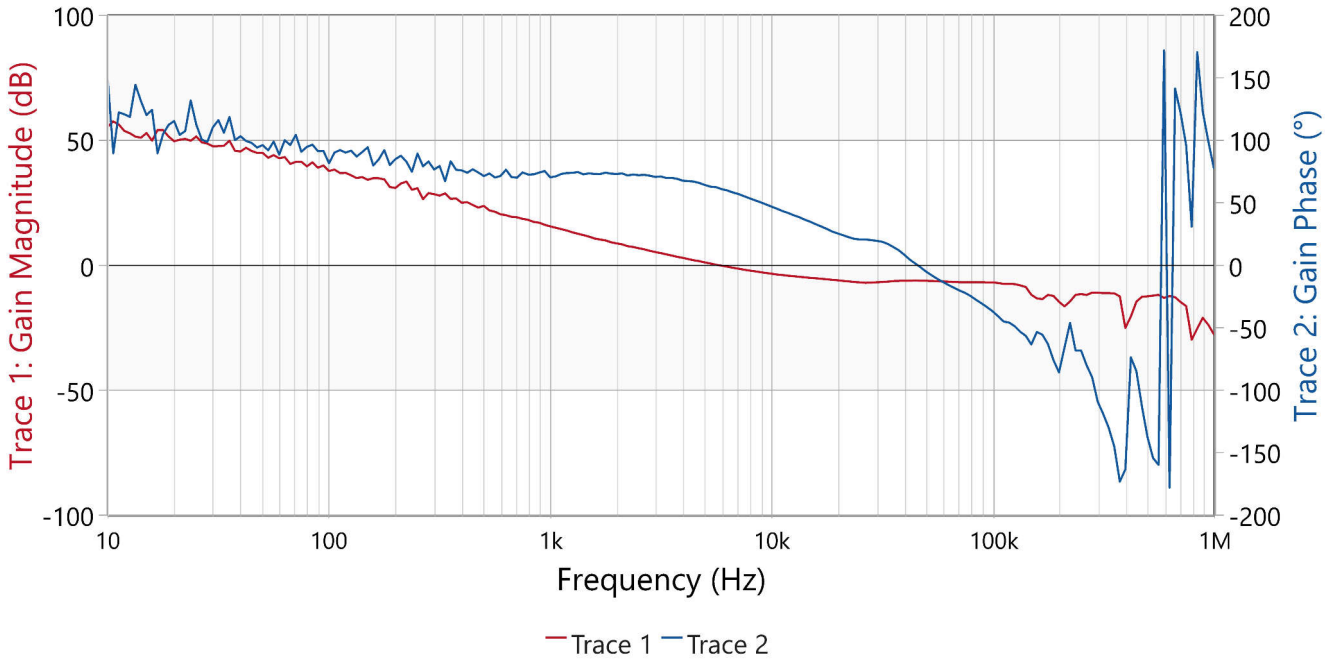



**Figure 3-25. Control Loop Response, VIN = 9.0V, IOUT = 17A**

# 4 Hardware Design Files

## 4.1 Schematic

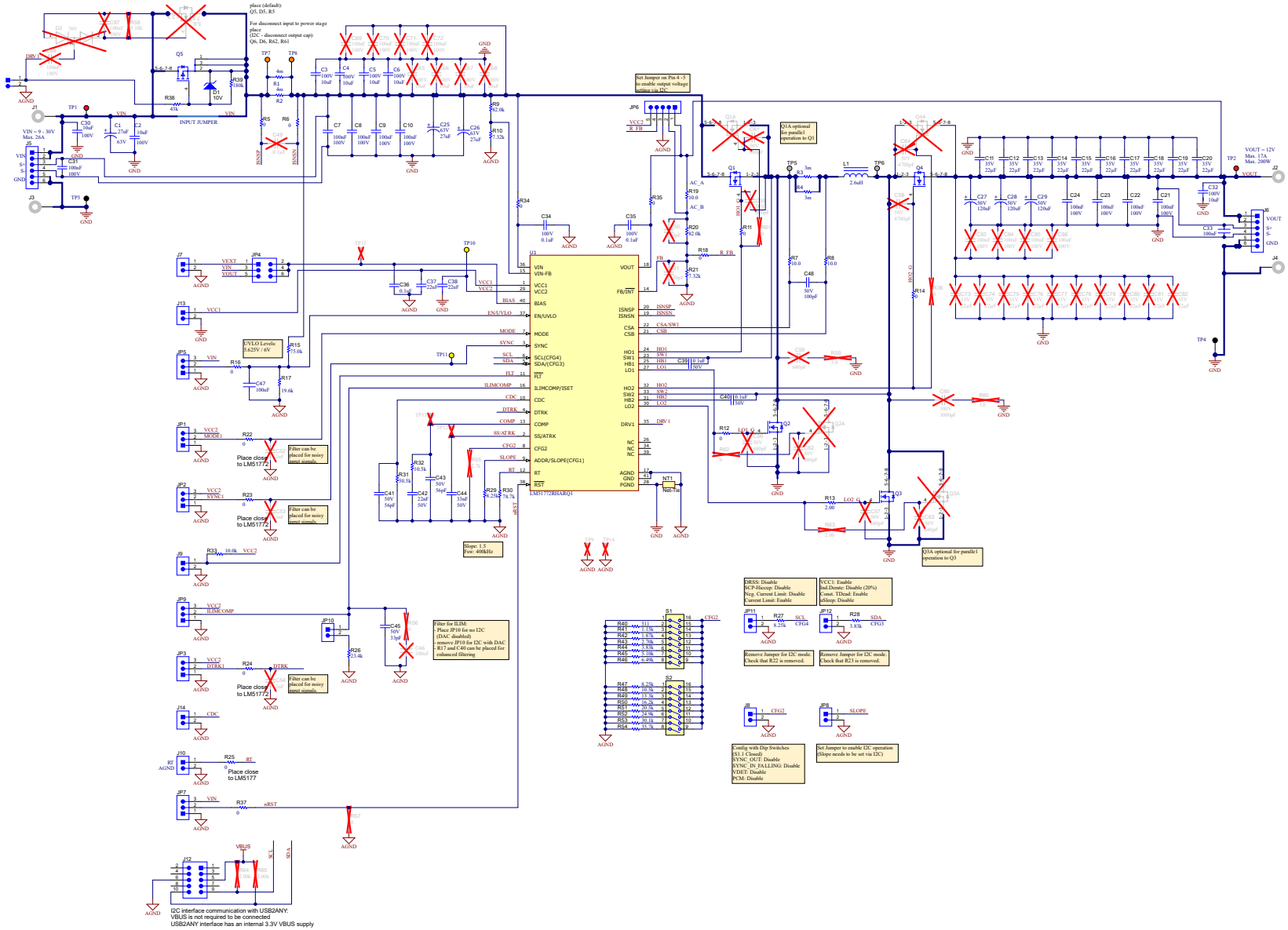
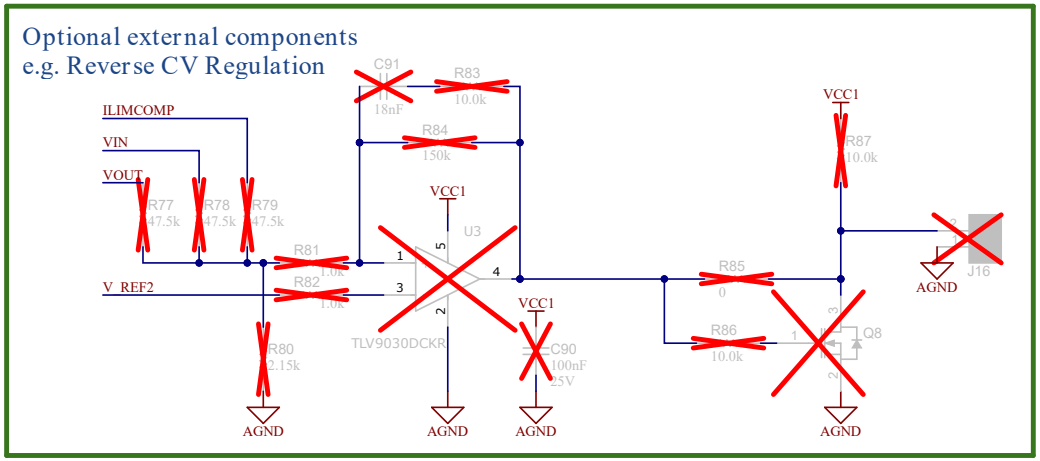
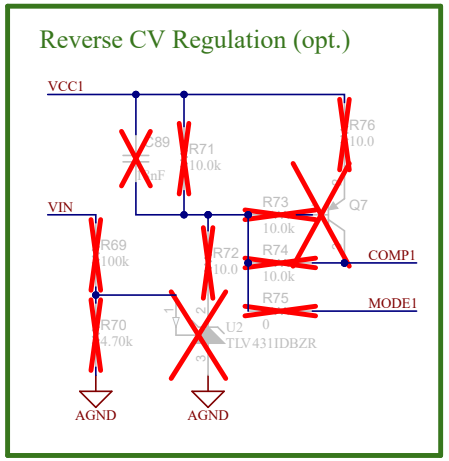


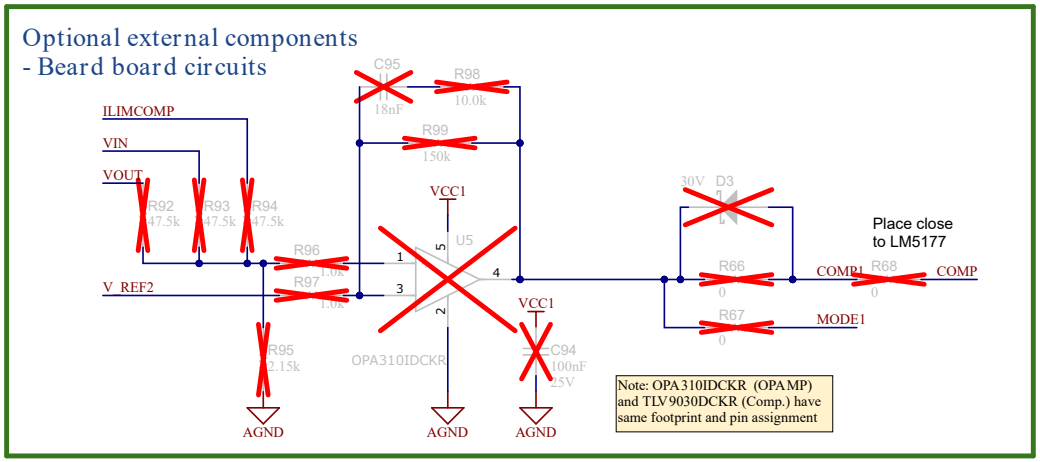
**Figure 4-1. 4-Switch Buck-Boost Controller Schematic**

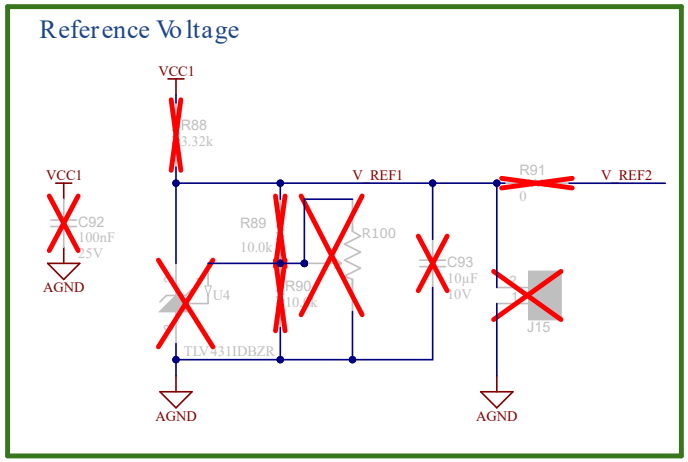
Optional external components
- Beard board circuits

This sheet contains footprint placeholder for compoents to extend the controller functions. Components and values are generic and can be



## 4.2 PCB Layout

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

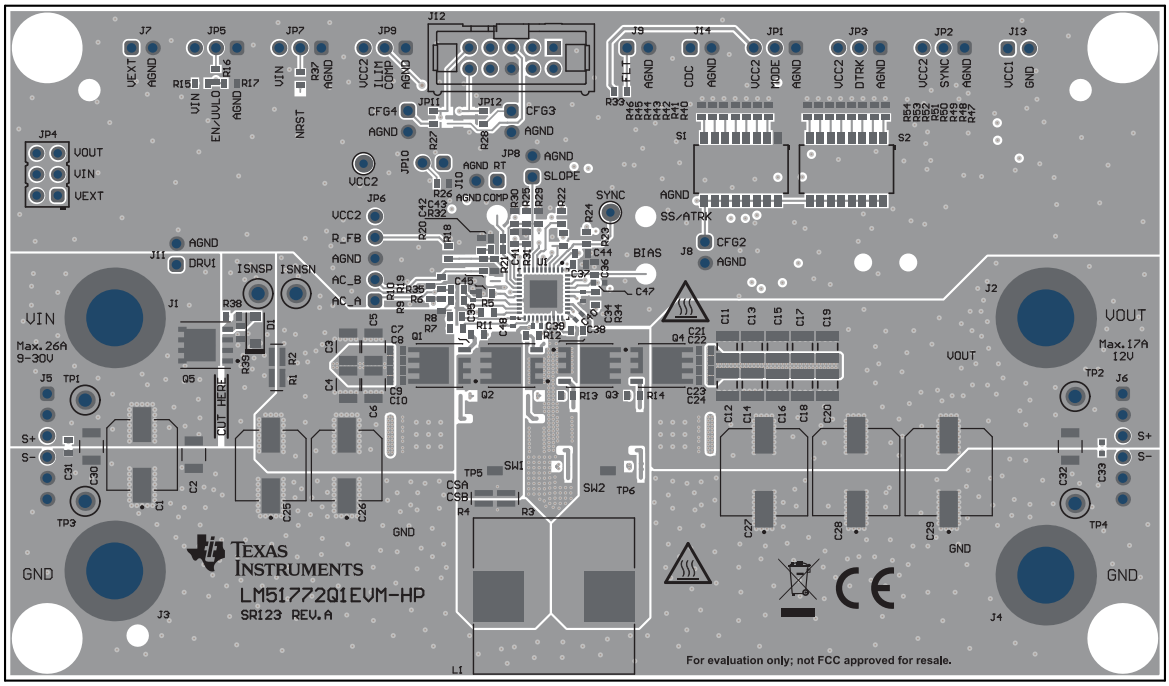



**Figure 4-2. Top Silkscreen**

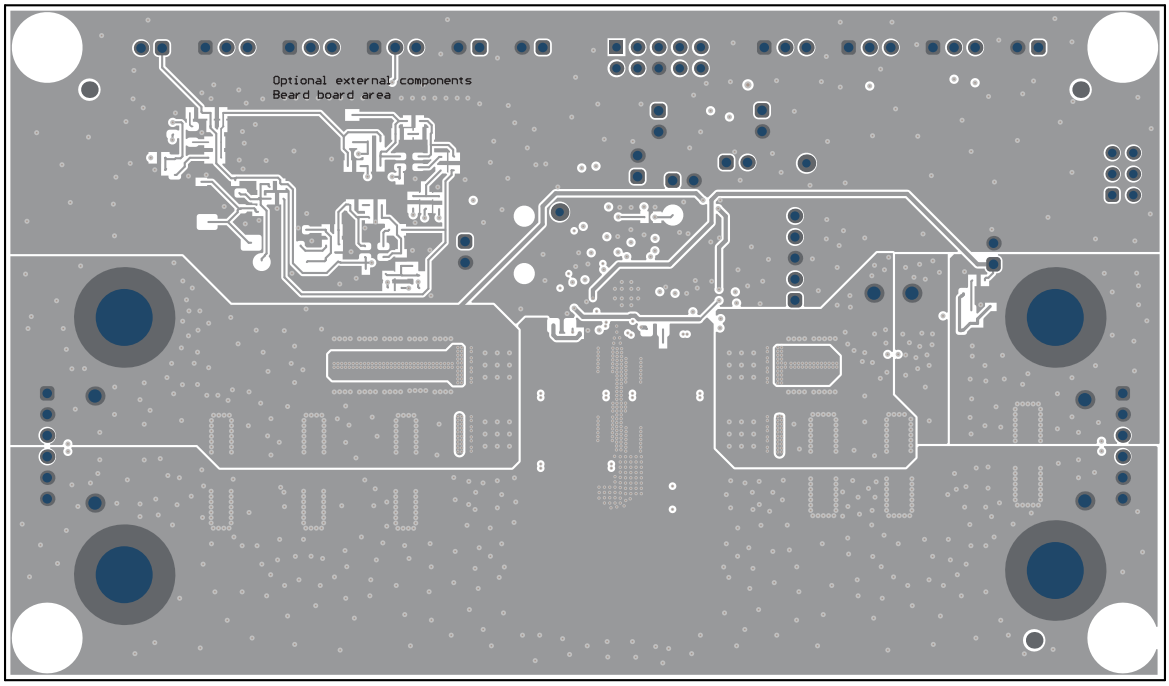



**Figure 4-3. Bottom Silkscreen**

## 4.2 PCB Layout (continued)

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

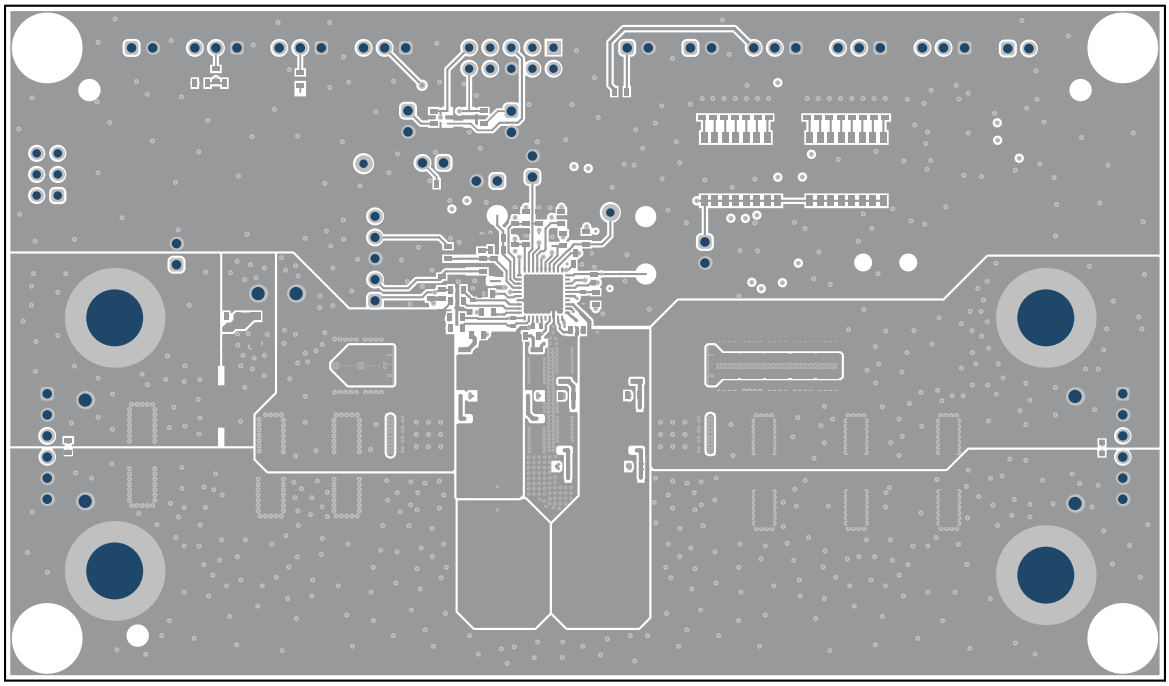


**Figure 4-4. Top Layer**

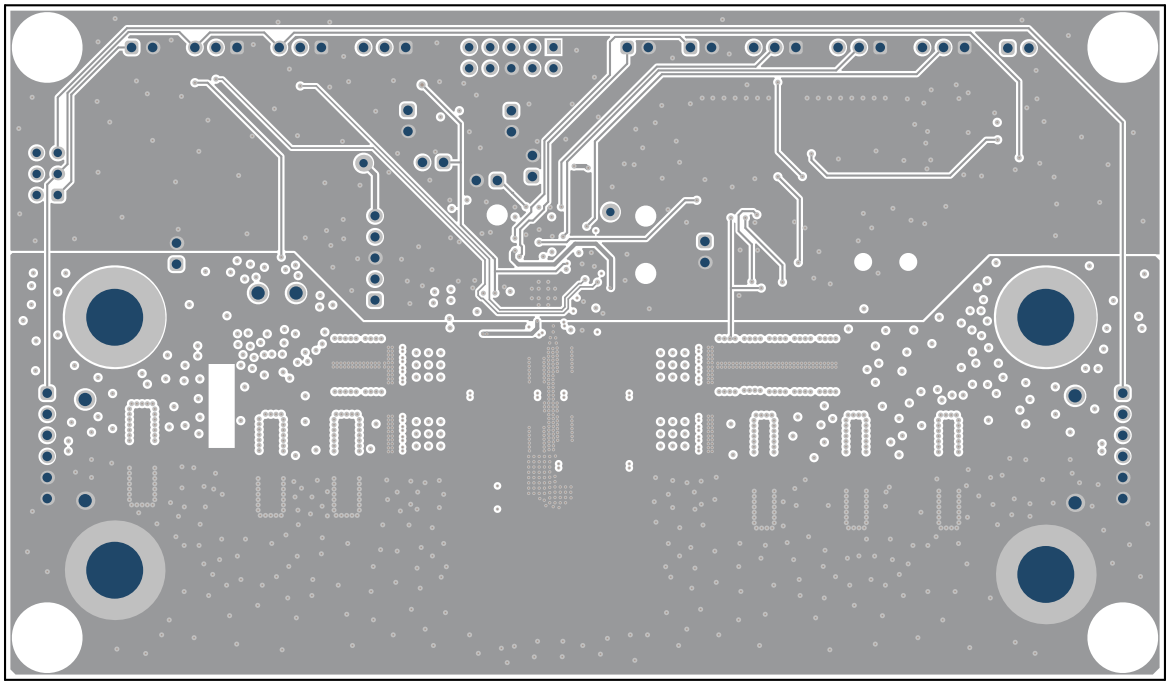


**Figure 4-5. Mid-Layer 1**

## 4.2 PCB Layout (continued)

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

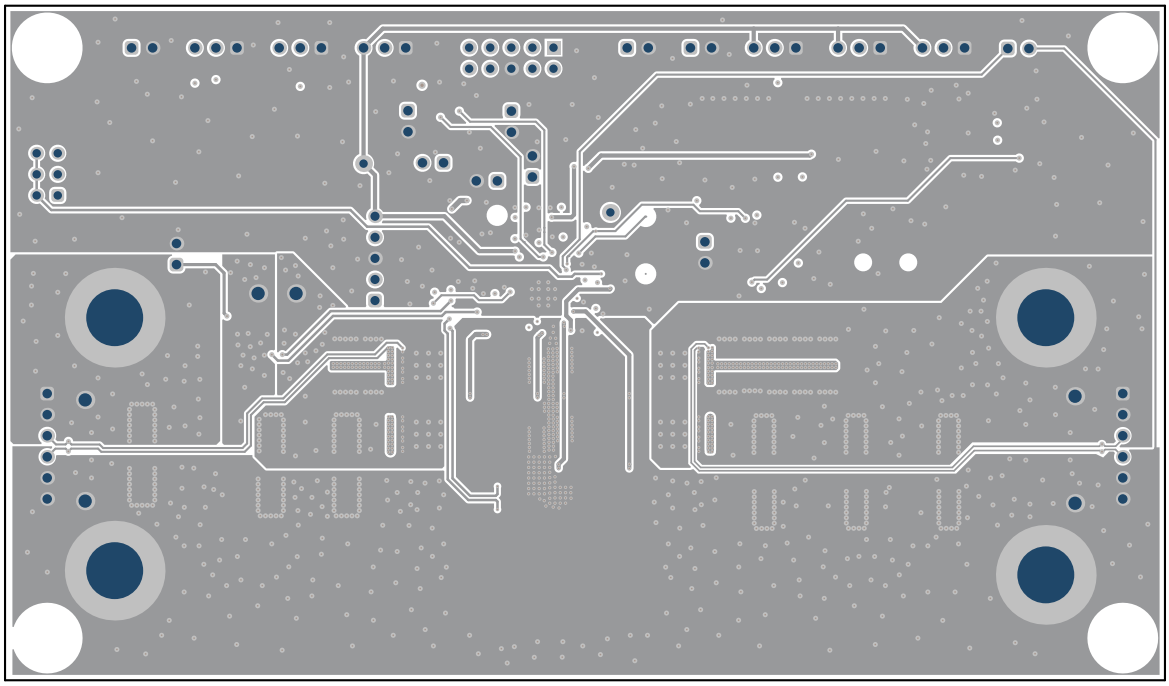


**Figure 4-6. Mid-Layer 2**

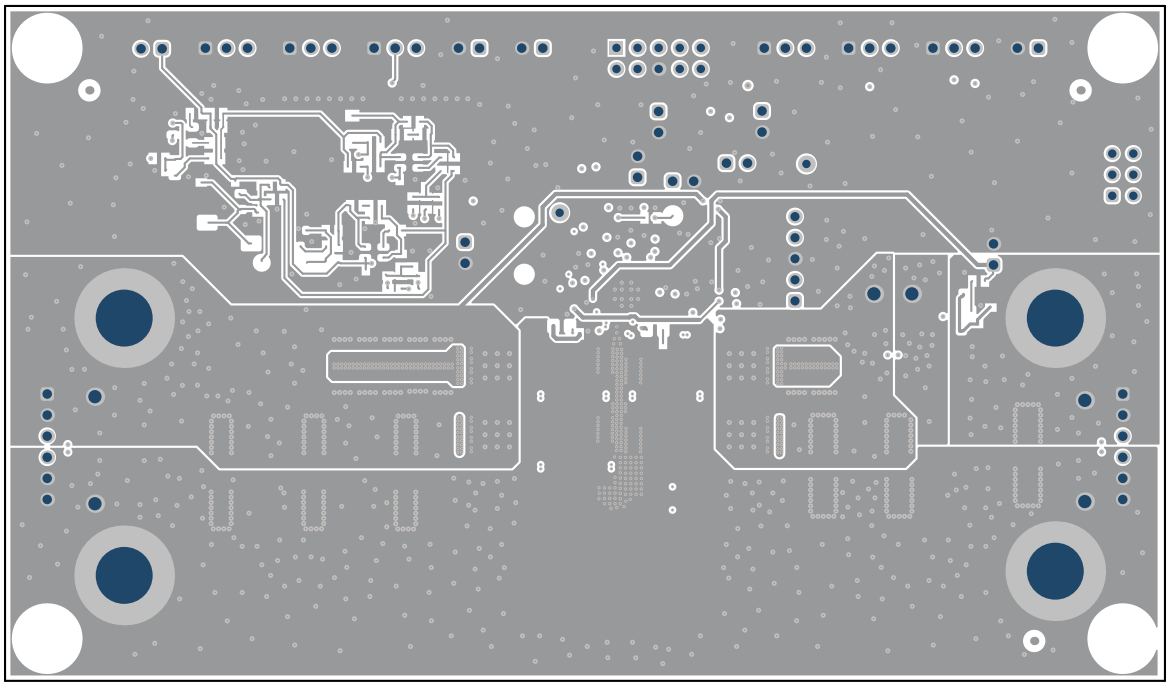


**Figure 4-7. Bottom Layer**

## 4.3 Bill of Materials

**Table 4-1. Bill of Material**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| C1, C25, C26 | 3 | 27µF | A768KE276M1JLAE054 | KEMET | Cap Aluminum Polymer 27uF 63V 20% Solder Cylindrical 54m Ohm 1175mA 2000 hr 125°C T/R |
| C2, C3, C4, C5, C6, C30, C32 | 7 | 10µF | C3225X7R2A106K250AC | TDK | 10µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric) |
| C7, C8, C9, C10, C21, C22, C23, C24, C31 | 9 | 0.1uF | GCJ188R72A104KA01D | MuRata | CAP, CERM, 0.1uF, 100V,+/-10%, X7R, AEC-Q200 Grade 1, 0603 |
| C11, C12, C13, C14, C15, C16, C17, C18, C19, C20 | 10 | 22uF | GMK325BJ226MM-P | Taiyo Yuden | CAP, CERM, 22µF, 35V,+/-20%, X5R, 1210 |
| C27, C28, C29 | 3 | 120µF | A768MS127M1HLAE024 | KEMET | 120µF 50V Aluminum - Polymer Capacitors Radial, Can - SMD 24mOhm 2000 Hrs @ 125°C |
| C33, C47 | 2 | | GCM188L81H104KA57D | Murata Electronics North America | 0.1µF ±10% 50V Ceramic Capacitor X8L 0603 (1608 Metric) |
| C34, C35 | 2 | 0.1uF | GRM155R62A104KE14D | MuRata | CAP, CERM, 0.1uF, 100V, +/-10%, X5R, 0402 |
| C36 | 1 | 0.1uF | CGA3E3X7S2A104K080AB | TDK | CAP, CERM, 0.1uF, 100V, +/-10%, X7S, AEC-Q200 Grade 1, 0603 |
| C37, C38 | 2 | 22µF | GRT188R61A226ME13D | Murata | Multi-Layer Ceramic Capacitor 22uF 10V X5R ±20% 0603 Paper T/R |
| C39, C40 | 2 | 0.1uF | GCM155R71H104KE02D | MuRata | CAP, CERM, 0.1uF, 50V, +/-10%, X7R, AEC-Q200 Grade 1, 0402 |
| C41 | 1 | 56pF | 06035A560FAT2A | AVX | CAP, CERM, 56pF, 50V, +/-1%, C0G/NP0, 0603 |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| C42 | 1 | 0.022uF | C0603X223K5RACTU | Kemet | CAP, CERM, 0.022 uF, 50V, +/- 10%, X7R, 0603 |
| C43 | 1 | 56pF | 06035A560JAT2A | AVX | CAP, CERM, 56pF, 50V, +/- 5%, C0G/NP0, 0603 |
| C44 | 1 | 0.033uF | 06035C333JAT2A | AVX | CAP, CERM, 0.033 uF, 50V, +/- 5%, X7R, 0603 |
| C45 | 1 | 33pF | CL10C330FB8NNNC | Samsung Electro-Mechanics | CAP, CERM, 33pF, 50V, +/- 5%, C0G/NP0, 0603 |
| C48 | 1 | 100pF | GRM1555C1H101JA01D | MuRata | CAP, CERM, 100pF, 50V, +/- 5%, C0G/NP0, 0402 |
| D1 | 1 | 10V | MMSZ4697T1G | ON Semiconductor | Diode, Zener, 10 V, 500mW, SOD-123 |
| J1, J2, J3, J4 | 4 | | 108-0740-001 | Cinch Connectivity | Standard Banana Jack, Uninsulated, 15A |
| J5, J6 | 2 | | 61300611121 | Wurth Elektronik | Header, 2.54mm, 6x1, Gold, TH |
| J7, J8, J9, J10, J11, J13, J14, JP8, JP10, JP11, JP12 | 11 | | 61300211121 | Wurth Elektronik | Header, 2.54mm, 2x1, Gold, TH |
| J12 | 1 | | N2510-6002-RB | 3M | Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH |
| JP1, JP2, JP3, JP5, JP7, JP9 | 6 | | 61300311121 | Wurth Elektronik | Header, 2.54mm, 3x1, Gold, TH |
| JP4 | 1 | | HTSW-103-07G-D | Samtec | Header, 2.54mm, 3x2, Gold, TH |
| JP6 | 1 | | 61300511121 | Wurth Elektronik | Header, 2.54mm, 5x1, Gold, TH |
| L1 | 1 | 2.6uH | 7443556260 | Wurth Elektronik | Inductor, Shielded Drum Core, WE-Superflux200, 2.6 uH, 31.5A, 0.0016ohm, SMD |
| Q1, Q2, Q3, Q4 | 4 | | IAUCN04S7L014ATMA1 | Infineon | N-Channel 40V 120A Surface Mount PG-TDSON-8-34 |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| Q5 | 1 | | SI7155DP-T1-GE3 | Vishay | Trans MOSFET P-CH -40V -100A 8-Pin SOIC - Tape and Reel |
| R1, R2 | 2 | 4m | KRL2012E-M-R004F-T5 | Susumu | 4 mOhms ±1% 1W Chip Resistor Wide 0805 (2012 Metric), 0508 Automotive AEC-Q200, Current Sense Metal Foil |
| R3, R4 | 2 | 3m | KRL2012E-M-R003F-T5 | Susumu | 3 mOhms ±1% 1W Chip Resistor Wide 0805 (2012 Metric), 0508 Automotive AEC-Q200, Current Sense Metal Foil |
| R5, R6, R11, R12, R14, R16, R18, R22, R23, R24, R25, R34, R35, R37 | 14 | 0 | RMCF0603ZT0R00 | Stackpole Electronics Inc | RES, 0, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R7, R8 | 2 | 10 | CRCW060310R0FKEAHP | Vishay-Dale | RES, 10.0, 1%, 0.25W, AEC-Q200 Grade 0, 0603 |
| R9, R20 | 2 | 82.0k | RC0603FR-0782KL | Yageo | RES, 82.0k, 1%, 0.1W, 0603 |
| R10, R21 | 2 | 7.32k | CRCW06037K32FKEA | Vishay-Dale | RES, 7.32k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R13 | 1 | 2 | MCT06030C2008FP500 | Vishay/Beyschlag | RES, 2.00, 1%, 0.125W, 0603 |
| R15 | 1 | 75.0k | RC0603FR-0775KL | Yageo | RES, 75.0k, 1%, 0.1W, 0603 |
| R17 | 1 | 19.6k | CRCW060319K6FKEA | Vishay-Dale | RES, 19.6k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R19 | 1 | 10 | RC0603FR-0710RL | Yageo | RES, 10.0, 1%, 0.1 W, 0603 |
| R26 | 1 | 23.4k | RT0603BRD0723K4L | Yageo America | RES, 23.4k, 0.1%, 0.1W, 0603 |
| R27, R29, R47 | 3 | 8.25k | RC0603FR-078K25L | Yageo | RES, 8.25k, 1%, 0.1W, 0603 |
| R28, R44 | 2 | 3.83k | CRCW06033K83FKEA | Vishay-Dale | RES, 3.83k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R30 | 1 | 78.7k | CRCW060378K7FKEA | Vishay-Dale | RES, 78.7k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R31 | 1 | 50.5k | RT0603BRD0750K5L | Yageo America | RES, 50.5k, 0.1%, 0.1W, 0603 |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| R32, R48 | 2 | 10.5k | CRCW060310K5FKEA | Vishay-Dale | RES, 10.5k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R33 | 1 | 10.0k | RT0603BRD0710KL | Yageo America | RES, 10.0k, 0.1%, 0.1W, 0603 |
| R38 | 1 | 43k | CRCW060343K0JNEA | Vishay-Dale | RES, 43k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603 |
| R39 | 1 | 180k | CRCW0603180KJNEA | Vishay-Dale | RES, 180k, 5%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R40 | 1 | 511 | CRCW0603511RFKEA | Vishay-Dale | RES, 511, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 |
| R41 | 1 | 1.15k | CRCW06031K15FKEA | Vishay-Dale | RES, 1.15k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R42 | 1 | 1.87k | RC0603FR-071K87L | Yageo | RES, 1.87k, 1%, 0.1W, 0603 |
| R43 | 1 | 2.70k | RC0603FR-072K7L | Yageo | RES, 2.70k, 1%, 0.1W, 0603 |
| R45 | 1 | 5.10k | RC0603FR-075K1L | Yageo | RES, 5.10k, 1%, 0.1W, 0603 |
| R46 | 1 | 6.49k | RC0603FR-076K49L | Yageo | RES, 6.49k, 1%, 0.1W, 0603 |
| R49 | 1 | 13.3k | RC0603FR-0713K3L | Yageo | RES, 13.3k, 1%, 0.1W, 0603 |
| R50 | 1 | 16.2k | CRCW060316K2FKEA | Vishay-Dale | RES, 16.2k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R51 | 1 | 20.5k | RC0603FR-0720K5L | Yageo | RES, 20.5k, 1%, 0.1W, 0603 |
| R52 | 1 | 24.9k | CRCW060324K9FKEA | Vishay-Dale | RES, 24.9k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R53 | 1 | 30.1k | CRCW060330K1FKEA | Vishay-Dale | RES, 30.1k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R54 | 1 | 35.7k | CRCW060335K7FKEA | Vishay-Dale | RES, 35.7k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| S1, S2 | 2 | | 218-8LPST | CTS Electrocomponents | Switch, SPST, 8 Pos, 25mA, 24VDC, SMD |
| TP1, TP2 | 2 | | 5010 | Keystone Electronics | Test Point, Multipurpose, Red, TH |
| TP3, TP4 | 2 | | 5011 | Keystone Electronics | Test Point, Multipurpose, Black, TH |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| TP5, TP6 | 2 | | S2761-46R | Harwin | Natural PC Test Point Brass, SMT |
| TP7, TP8 | 2 | | 5013 | Keystone Electronics | Test Point, Multipurpose, Orange, TH |
| TP10, TP11 | 2 | | 5004 | Keystone Electronics | Test Point, Miniature, Yellow, TH |
| U1 | 1 | | LM51772RHARQ1 | Texas Instruments | 48V 4 Switch Buck-Boost Controller with I2C interface |
| C46 | 0 | | GCM188L81H104KA57D | Murata Electronics North America | 0.1µF ±10% 50V Ceramic Capacitor X8L 0603 (1608 Metric) |
| C49 | 0 | 0.1uF | 0402BB104KW500 | Passive Plus | CAP, CERM, 0.1µF, 50V,+/- 10%, X7R, 0402 |
| C50 | 0 | 20pF | GRM1885C2A200JA01D | MuRata | CAP, CERM, 20pF, 100V, +/- 5%, C0G/NP0, 0603 |
| C51 | 0 | 150pF | GRM1885C1H151JA01D | MuRata | CAP, CERM, 150pF, 50V, +/- 5%, C0G/NP0, 0603 |
| C52, C53, C54 | 0 | 1000pF | 06031C102JAT2A | AVX | CAP, CERM, 1000 pF, 100V, +/- 5%, X7R, 0603 |
| C55, C56, C57, C61, C62, C63 | 0 | 680pF | GCM1555C1H681FA16D | MuRata | CAP, CERM, 680pF, 50V,+/- 1%, C0G/NP0, AEC-Q200 Grade 1, 0402 |
| C58, C64 | 0 | 4700pF | GRM155R71H472KA01D | MuRata | CAP, CERM, 4700 pF, 50V, +/- 10%, X7R, 0402 |
| C59 | 0 | 680pF | GRM2195C2A681JA01D | MuRata | CAP, CERM, 680pF, 100V, +/- 5%, C0G/NP0, 0805 |
| C60 | 0 | 3000pF | GRM2165C2A302JA01D | MuRata | CAP, CERM, 3000 pF, 100V, +/- 5%, C0G/NP0, 0805 |
| C65, C66, C67, C68 | 0 | 10µF | C3225X7R2A106K250AC | TDK | 10µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric) |
| C69, C70, C71, C72, C83, C84, C85, C86, C87, C88 | 0 | 0.1uF | GCJ188R72A104KA01D | MuRata | CAP, CERM, 0.1uF, 100V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603 |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| C73, C74, C75, C76, C77, C78, C79, C80, C81, C82 | 0 | 22uF | GMK325BJ226MM-P | Taiyo Yuden | CAP, CERM, 22µF, 35V,+/- 20%, X5R, 1210 |
| C89, C91, C95 | 0 | 0.018uF | C0603C183K1RACTU | Kemet | CAP, CERM, 0.018 uF, 100V, +/- 10%, X7R, 0603 |
| C90, C92, C94 | 0 | 0.1uF | C0603X104K3RACTU | Kemet | CAP, CERM, 0.1uF, 25V, +/- 10%, X7R, 0603 |
| C93 | 0 | 10uF | GRM188R61A106KE69D | MuRata | CAP, CERM, 10µF, 10V,+/- 10%, X5R, 0603 |
| D2 | 0 | | BAS70-04E3-18 | Vishay | Diode Array 1 Pair Series Connection Schottky 70V 200mA (DC) Surface Mount TO-236-3, SC-59, SOT-23-3 |
| D3 | 0 | 30V | BAT54T1G | ON Semiconductor | Diode, Schottky, 30V, 0.2A, SOD-123 |
| H1, H2, H3, H4 | 0 | | NY PMS 440 0025 PH | B&F Fastener Supply | Machine Screw, Round, #4-40x 1/4, Nylon, Philips panhead |
| H5, H6, H7, H8 | 0 | | 1902C | Keystone | Standoff, Hex, 0.5"L #4-40 Nylon |
| J15, J16 | 0 | | 61300211121 | Wurth Elektronik | Header, 2.54mm, 2x1, Gold, TH |
| Q1A, Q2A, Q3A, Q4A | 0 | | IAUCN04S7L014ATMA1 | Infineon | N-Channel 40V 120A Surface Mount PG-TDSON-8-34 |
| Q6 | 0 | 60V | CSD18540Q5B | Texas Instruments | MOSFET, N-CH, 60 V, 100A, DNK0008A (VSON-CLIP-8) |
| Q7 | 0 | 45V | BC807-40LT1G | ON Semiconductor | Transistor, PNP, 45V, 0.5A, AEC-Q101, SOT-23 |
| Q8 | 0 | 60V | 2N7002W-7F | Diodes Inc. | MOSFET, N-CH, 60 V, 0.115A, SOT-323 |
| R36, R56, R57, R61, R62, R66, R67, R68, R75, R85, R91 | 0 | 0 | RMCF0603ZT0R00 | Stackpole Electronics Inc | RES, 0, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R55 | 0 | 2.7k | CRCW06032K70JNEA | Vishay-Dale | RES, 2.7k, 5%, 0.1W, AEC-Q200 Grade 0, 0603 |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| R58 | 0 | 5.10k | RC0603FR-075K1L | Yageo | RES, 5.10k, 1%, 0.1W, 0603 |
| R59, R60 | 0 | 3 | CRCW06033R00JNEA | Vishay-Dale | RES, 3.0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603 |
| R63 | 0 | 2 | MCT06030C2008FP500 | Vishay/Beyschlag | RES, 2.00, 1%, 0.125W, 0603 |
| R64, R65 | 0 | 2.00k | RC0603FR-072KL | Yageo | RES, 2.00k, 1%, 0.1W, 0603 |
| R69 | 0 | 100k | RC0603FR-07100KL | Yageo | RES, 100k, 1%, 0.1W, 0603 |
| R70 | 0 | 4.70k | RC0603FR-074K7L | Yageo | RES, 4.70k, 1%, 0.1W, 0603 |
| R71, R73, R74, R83, R98 | 0 | 10.0k | CRCW060310K0FKEA | Vishay-Dale | RES, 10.0k, 1%, 0.1W, AEC-Q200 Grade 0, 0603 |
| R72, R76 | 0 | 10 | RC0603FR-0710RL | Yageo | RES, 10.0, 1%, 0.1 W, 0603 |
| R77, R78, R79, R92, R93, R94 | 0 | 47.5k | RC0603FR-0747K5L | Yageo | RES, 47.5k, 1%, 0.1W, 0603 |
| R80, R95 | 0 | 2.15k | RC0603FR-072K15L | Yageo | RES, 2.15k, 1%, 0.1W, 0603 |
| R81, R82, R96, R97 | 0 | 1.0k | RC0603JR-071KL | Yageo | RES, 1.0k, 5%, 0.1W, 0603 |
| R84, R99 | 0 | 150k | RC0603FR-07150KL | Yageo | RES, 150k, 1%, 0.1W, 0603 |
| R86, R87, R89, R90 | 0 | 10.0k | RT0603BRD0710KL | Yageo America | RES, 10.0k, 0.1%, 0.1W, 0603 |
| R88 | 0 | 3.32k | RC0603FR-073K32L | Yageo | RES, 3.32k, 1%, 0.1W, 0603 |
| R100 | 0 | 10kΩ | ST-5ETW103 | Nidec Copal Electronics | 10 kOhms 0.25W, 1/4W Gull Wing Surface Mount Trimmer Potentiometer Cermet 14.0 Turn Top Adjustment |
| TP9, TP14 | 0 | | 5001 | Keystone Electronics | Test Point, Miniature, Black, TH |
| TP12, TP13, TP15 | 0 | | 5004 | Keystone Electronics | Test Point, Miniature, Yellow, TH |
| U2, U4 | 0 | | TLV431IDBZR | Texas Instruments | Low Voltage Adjustable Precision Shunt Regulator, 39ppm / degC, 15mA, -40 to 85 degC, 3-pin SOT-23 (DBZ), Green (RoHS & no Sb/Br) |

**Table 4-1. Bill of Material (continued)**

| Designator | Quantity | Value | PartNumber | Manufacturer | Description |
|---|---|---|---|---|---|
| U3 | 0 | | TLV9030DCKR | Texas Instruments | Single low-voltage comparator with push-pull output 5-SC70 -40 to 125 |
| U5 | 0 | | OPA310IDCKR | Texas Instruments | Single, 5.5V, 3MHz high-output-current (150mA) fast-shutdown (1µs) operational amplifier 5-SC70 -40 to 125 |

# 5 Additional Information

## 5.1 Trademarks

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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

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

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:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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

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