![Texas Instruments logo]

# LMQ61460EVM-400K User's Guide

The LMQ61460-Q1 evaluation module (EVM) is designed to help customers evaluate the performance of the LMQ61460-Q1 synchronous step-down voltage converter. This EVM implements the LMQ61460-Q1 in a 14-pin wettable flanks Hotrod™ package, as shown in Table 1. It is capable of delivering 5-V output voltage and up to 6-A load current switching at 400 kHz with exceptional efficiency and output accuracy in a very small solution size. The EVM provides multiple power connectors and test points. In addition to an optimized EMI board layout, the LMQ61460-Q1 uses integrated bypass capacitors which results in great EMI performance.

**Table 1. Device and Package Configurations**

| CONVERTER | IC | PACKAGE |
|---|---|---|
| U1 | LMQ61460-Q1 | 14-pin wettable flanks Hotrod package 4.0 mm × 3.5 mm × 1.0 mm |
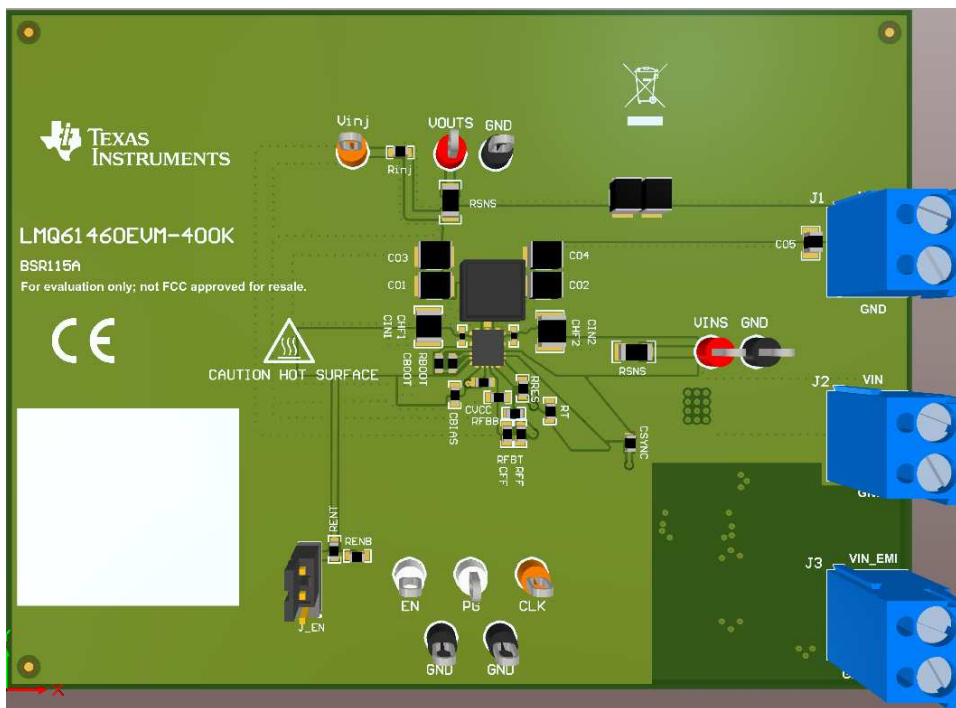


**Figure 1. LMQ61460EVM-400K Top View**

**Contents**

## Trademarks

Hotrod is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

# 1 Introduction

## 1.1 *LMQ61460-Q1 Synchronous Step-Down Voltage Converter*

The LMQ61460-Q1 is an easy-to-use synchronous step-down DC/DC converter capable of delivering up to 6 A of load current from a supply voltage ranging from 3 V to 36 V. The LMQ61460-Q1 provides exceptional efficiency and output accuracy in a very small solution size. The LMQ61460-Q1 is capable of delivering 6 A of load current and implements peak current mode control. The following are additional features that provide both flexible and easy-to-use solutions for a wide range of applications:

- Adjustable switching frequency (RT)
- Synchronization to an external clock (CLK jumper)
- FPWM variant (LMQ61460AFS) (IC swap)
- Power-good flag (PG jumper)
- Precision enable (EN jumper with RENT and RENB resistors)

Automatic frequency foldback at light load and optional external bias improve efficiency over the entire load range. The device requires few external components and has a pinout designed for optimal EMI and thermal performance. Protection features include the following:

- Thermal shutdown
- Input undervoltage lockout
- Cycle-by-cycle current limiting
- Hiccup short-circuit protection

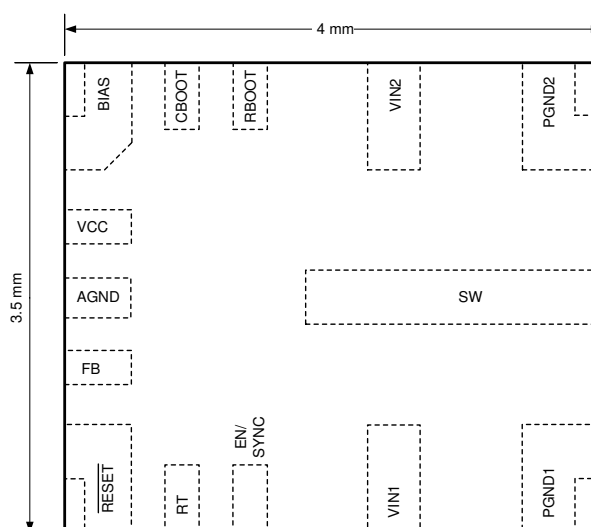For a quick reference, Figure 2 shows the pin configuration of the LMQ61460-Q1.

**Figure 2. LMQ61460-Q1 Pin Configuration (Top View)**

## 1.2 *LMQ61460-Q1 Evaluation Module*

The LMQ61460EVM-400K is populated with the LMQ61460AASQRJRRQ1 which automatically reduces frequency at light loads (PFM - pulse frequency modulation). This IC can be replaced with the LMQ61460AFSQRJRRQ1 for a constant switching frequency across load (FPWM - forced pulse width modulation).

## 2 Quick Start Guide

1. Connect the voltage supply between the VIN and GND connectors or between VIN_EMI and GND_EMI to include the on-board input filter in the input path. Use short and thick gauge wires to minimize inductance and IR drop. Note that sense points for $V_{IN}$ and $V_{OUT}$ are provided.

2. Connect the load of the converter between VOUT and GND connectors using short and thick wires.

3. Set the supply voltage at an appropriate level between 6 V to 36 V. The 6 V minimum input voltage ensures enough head room for $V_{OUT}$ to equal 5 V at a 6 A load current. Set the current limit of the supply to an appropriate level to supply needed current and protection.

4. Turn on the power supply. With the default configuration, the EVM powers up and provides $V_{OUT}$ equal to 5 V.

5. Monitor the output voltage with sense points. The maximum load current is 6 A with the LMQ61460-Q1. Note that the maximum output current may need to derate if ambient temperature is high, especially if device is operated at higher frequency, that is 2.2 MHz.

See Figure 4 for connector locations.

| **CAUTION** |
| --- |
| Caution Hot surface. Contact may cause burns. Do not touch. |
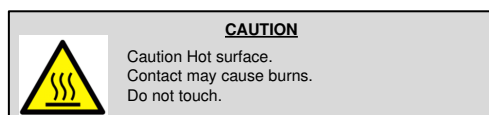
# 3 Detailed Descriptions

This section describes the connectors on the EVM and how to properly connect, set up, and use the EVM. See Figure 1 for a top view of the EVM.

**VOUT —**Output voltage of the converter

>VOUT connectors connect to the power inductor and output capacitors. Connect the load between the VOUT connector and the GND connector to provide load current. Connect the loading device to the board with short and thick wires to handle the large DC output current.

**GND —**Ground of the converter

>The GND is connected to the PGND and AGND pins of the device as well as the ground of the input and output capacitors. The GND connections next to VIN, VIN_EMI, and VOUT connectors are meant for current return path for the supply voltage and load, respectively. Connectors are provided in pairs to allow easy and accurate sensing of voltages. Connect to supply and load grounds with short and thick wires. Other GND connectors are for signal measurement and probing.

**$V_{IN}$—** Input voltage to the converter

>The $V_{IN}$ connector connects to the input capacitors and the VIN pins of the LMQ61460-Q1. Connect the supply voltage from a power supply or a battery between VIN and GND connectors as power input to the device. The input voltage ($V_{IN}$) range must be higher than 3.9 V for the device to start up and above 3 V to maintain operation. A $V_{IN}$ higher than 6 V provides a regulated 5-V output voltage. Maximum $V_{IN}$ is limited to 36 V to avoid damaging the device. The current limit on the supply must be high enough to provide the needed supply current. The supply voltage must be connected to the board with short and thick wires to handle the required input current at maximum load current. If long cables are used to power up the board, damping must be provided by adding CFLT3 and RFLT3 to avoid oscillation between the cable parasitic inductance and the existing low-ESR ceramic capacitors.

**VIN_EMI —**Low EMI option

>If the input filter is required, connect the supply voltage between VIN_EMI and GND_EMI. The supply voltage must be connected to the board with short and thick wires.

>The input filter consists of the following: CF1, CF2, CF3, CF4, CF5, CF6, and L2. CD1, CD2, RD1, and RD2 are provided to allow more options for filter optimization. To include the input filter in the power path, connect the supply voltage between the VIN_EMI and GND_EMI connectors. The output of the filter is connected to $V_{IN}$, which is connected to the $V_{IN}$ pins of the LMQ61460-Q1.

>Conducted EMI arises from the operation of switching circuits.

**GND_EMI —**Ground return for the input filter

>This is the current return path for the supply connected to VIN_EMI. It provides a short-loop connection to the input filter capacitors to best filter the conducted noise generated from the PCB. Use VIN_EMI and GND_EMI connection if input filter is used and conducted EMI test is desired.

**CLK —**For synchronization clock input

>The CLK input connector is designed for external clock input to the EN/SYNC pin. Switching action of the buck is synchronized to the external clock when it is present. The operation mode automatically changes to forced PWM mode, maintaining a constant switching frequency over the entire load range while the clock signal is present.

**EN —** To monitor the EN pin or control EN signal

>This test point is used to monitor the voltage on the device EN pin. By default, the EN pin is connected to the mid-point of an enable divider. Note that the lower resistor in this divider, RENB, is not populated so the IC turns on by default. Populate RENB to adjust UVLO. Apply a voltage to EN to externally enable or disable the device.

**PG —** To monitor the PGOOD/RESET pin

>The PGOOD flag indicates whether the output voltage is within the regulation band. The RESET pin (synonymous with PGOOD pin) of the device is an open-drain output and is pulled up to $V_{OUT}$ through a 100 k resistor. This pin pulls to GND when the output voltage is out of regulation.

**Vinj —** For measuring AC response

A low value resistor, Rinj, is placed between VOUT and this node. The feedback divider of the board is connected to this node. An AC signal is applied across Rinj when taking measurements for bode plots.

**VOUTS —** VOUT sense

This connector is provided for measuring the output voltage accurately.

**VINS —** VIN sense

This connector is provided for measuring the input voltage accurately.

# 4 Schematic

The bill of materials is tabulated in *Section 7*. In addition, Figure 3 shows the corresponding schematic.

**Figure 3. LMQ61460EVM-400K Schematic**

**NOTE:** Long leads and additional inductance in used to power the DC/DC may cause issues for ideal device operation. RD2, CD2, RD1, and CD1 are placeholders for damping networks to be populated. For more information regarding this topic, reference the *EMI Filter Components and Their Nonidealities for Automotive DC/DC Regulators Technical Brief*.

## 4.1 Alternative BOM Configurations

**Table 2. BOM Configurations**

| VOUT | FREQUENCY | RFBB | RT | COUT | CIN + CHF | L1 |
|------|-----------|------|-----|------|-----------|-----|
| 3.3 V | 400 kHz | 43.2 kΩ | 33.2 kΩ | 6 x 22 µF | 2 x 4.7 µF + 2 x 100 nF | 4.7 µH (XHMI6060) |
| 3.3 V | 2100 kHz | 43.2 kΩ | 6.04 kΩ | 3 x 22 µF | 2 x 4.7 µF + 2 x 100 nF | 1 µH (XEL5030) |
| 5 V | 400 kHz | 24.9 kΩ | 33.2 kΩ | 4 x 22 µF | 2 x 4.7 µF + 2 x 100 nF | 4.7 µH (XHMI6060) |
| 5 V | 2100 kHz | 24.9 kΩ | 6.04 kΩ | 3 x 22 µF | 2 x 4.7 µF + 2 x 100 nF | 1 µH (XEL5030) |

## 5 Board Layout

Figure 4 through Figure 8 show the board layout for the LMQ61460-Q1 EVM. The EVM offers resistors, capacitors, and test points to configure the following:

- Output voltage (RFBT and RFBB)
- Precision enable pin (RENT and RENB)
- Set frequency (RT)
- External clock synchronization (CLK jumper)

The 14-pin Hotrod package with integrated capacitors offers a very small size and low-noise solution. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to route signals and dissipate heat with an array of thermal vias to connect to all four layers.

Test points have been provided for ease of use to connect the power supply and required load, and to monitor critical signals.

The board measures 3.00" x 4.00" (76mm x 101mm).



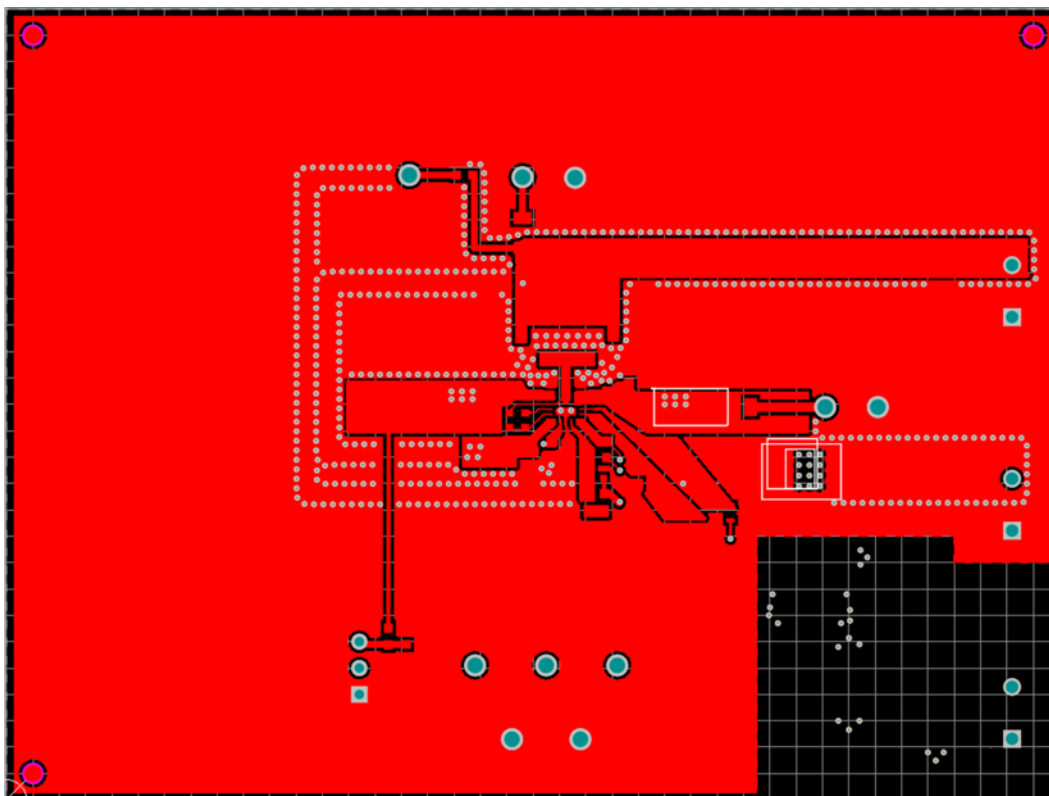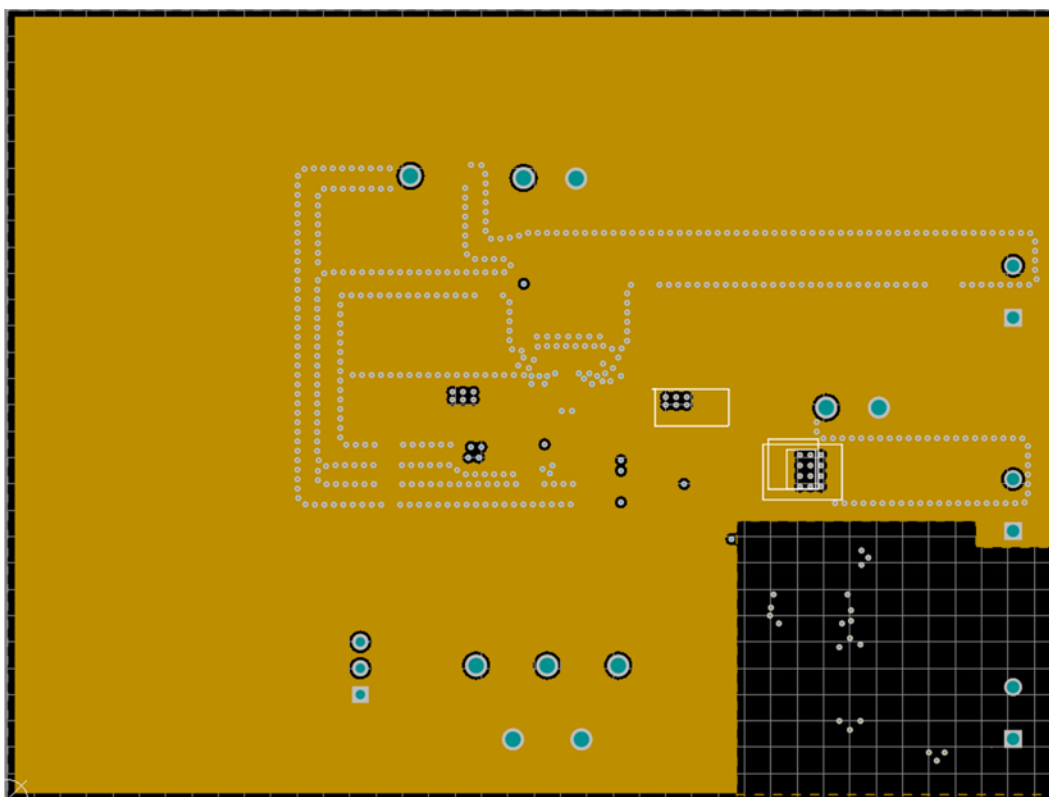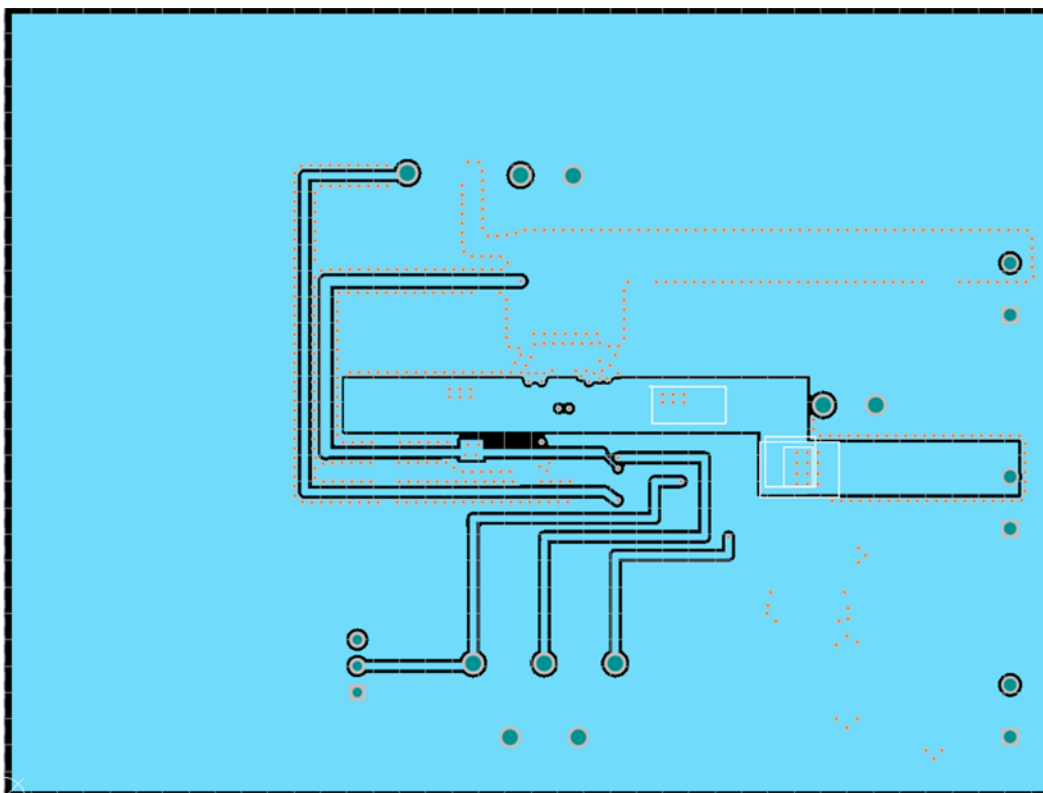**Figure 4. Top View with Silkscreen**

**Figure 5. Top Layer**



**Figure 6. Signal Layer 1 - Ground Plane**
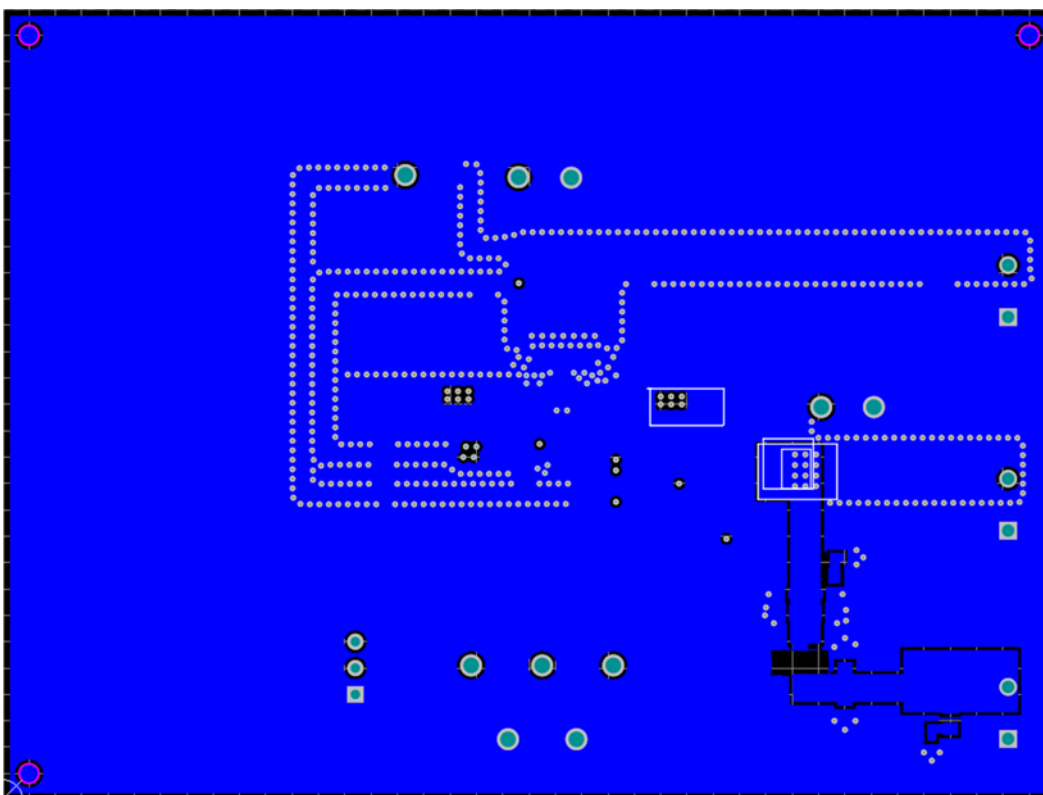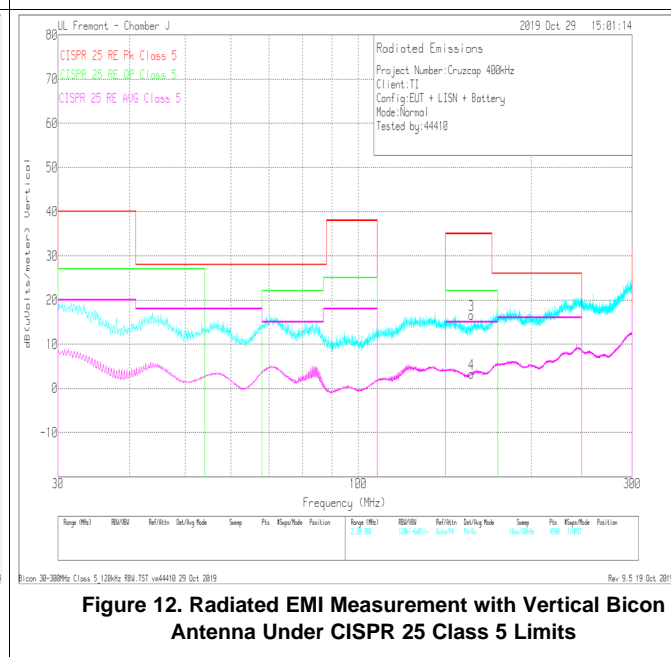
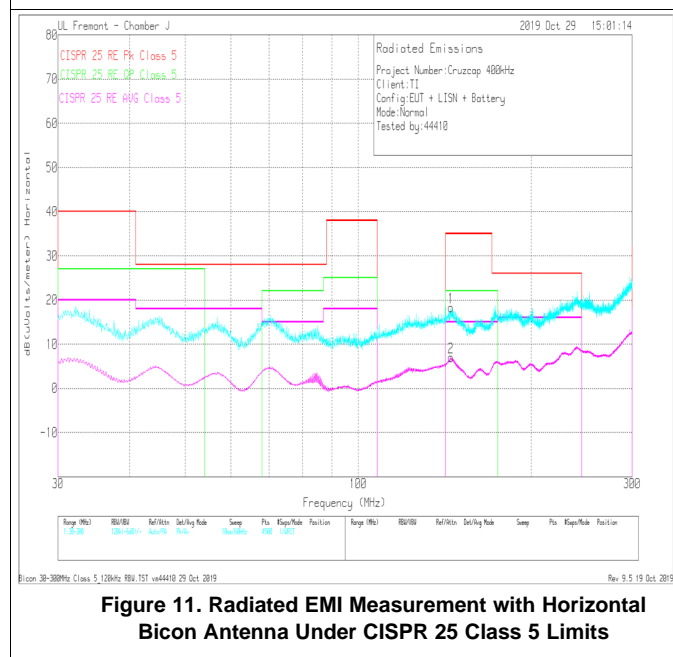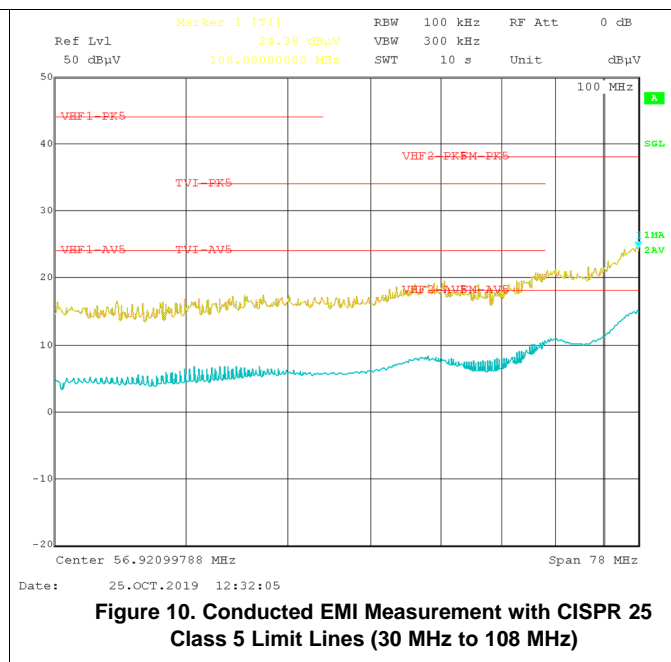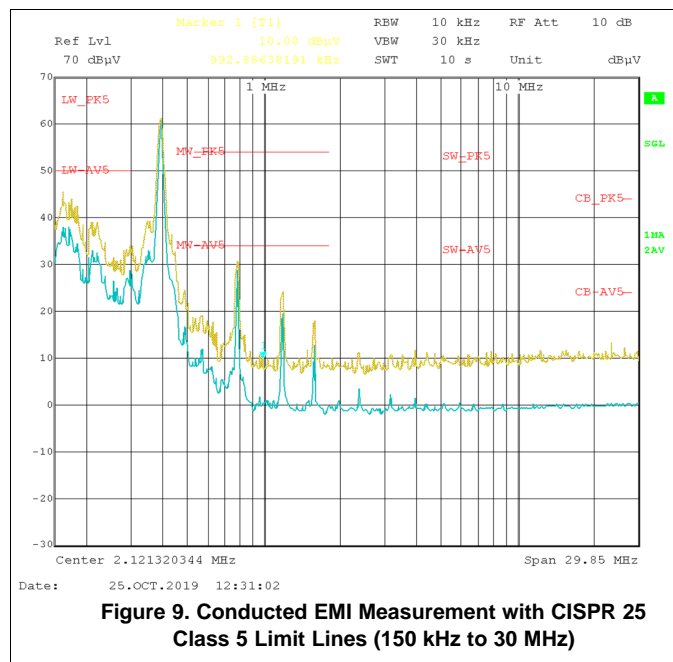**Figure 7. Signal Layer 2 - Routing**



**Figure 8. Bottom Layer**

# 6 LMQ61460EVM-400K Board Test Results

## 6.1 EMI

The EMI measurements were taken following CISPR 25, Class 5 standards. The measurements were taken at 13.5 VIN, 5 VOUT with a 6 A load switching at 400kHz.



**Figure 9. Conducted EMI Measurement with CISPR 25 Class 5 Limit Lines (150 kHz to 30 MHz)**



**Figure 10. Conducted EMI Measurement with CISPR 25 Class 5 Limit Lines (30 MHz to 108 MHz)**



**Figure 11. Radiated EMI Measurement with Horizontal Bicon Antenna Under CISPR 25 Class 5 Limits**



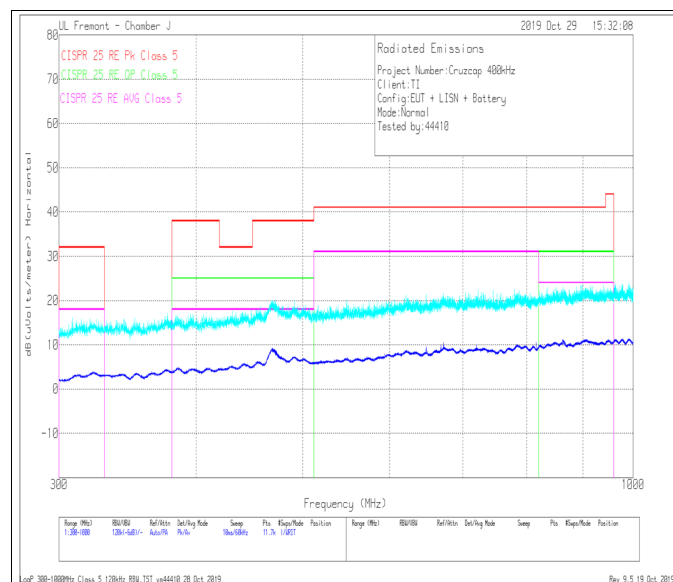**Figure 12. Radiated EMI Measurement with Vertical Bicon Antenna Under CISPR 25 Class 5 Limits**

**Figure 13. Radiated EMI Measurement with Horizontal Log Antenna Under CISPR 25 Class 5 Limits**
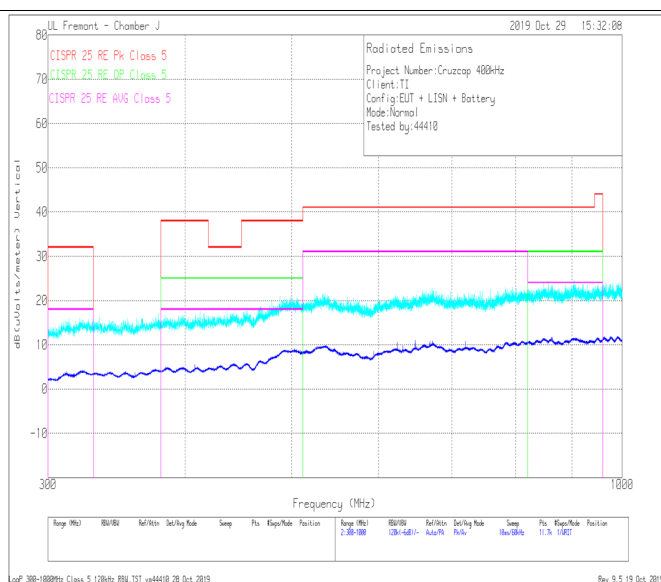


**Figure 14. Radiated EMI Measurement with Vertical Log Antenna Under CISPR 25 Class 5 Limits**

## 7   Bill of Materials

The bill of materials is shown Table 3 for the LMQ61460EVM-400K.

**Table 3. LMQ61460EVM-400K EVM Bill of Materials**

| DESIGNATOR | QUANTITY | VALUE | DESCRIPTION | PACKAGE REFERENCE | PART NUMBER | MANUFACTURER |
|---|---|---|---|---|---|---|
| C1, C4 | 2 | 4.7 µF | CAP, CERM, 4.7 µF, 50 V, ±20%, X7R, AEC-Q200 Grade 1, 1210 | 1210 | UMK325B7475MMHT | Taiyo Yuden |
| C2, C3 | 2 | 0.022 µF | CAP, CERM, 0.022 µF, 50 V, ±10%, X7R, 0402 | 0402 | GRM155R71H223KA12D | MuRata |
| C5 | 1 | 1 µF | CAP, CERM, 1 µF, 25 V, ±10%, X7R, 0805 | 0805 | C0805C105K3RACTU | Kemet |
| C6, C7, C8, C9 | 4 | 22 µF | CAP, CERM, 22 µF, 16 V, ±20%, X7R, AEC-Q200 Grade 1, 1210 | 1210 | CGA6P1X7R1C226M250AC | TDK |
| C12 | 1 | 1000 pF | CAP, CERM, 1000 pF, 50 V, ±0%, X7R, 0603 | 0603 | C0603C102K5RACTU | Kemet |
| C13 | 1 | 0.1 µF | CAP, CERM, 0.1 µF, 10 V, ±10%, X7R, 0603 | 0603 | C0603X104K8RACTU | Kemet |
| C15 | 1 | 1 µF | CAP, CERM, 1 µF, 16 V, ±10%, X7R, 0603 | 0603 | 885012206052 | Wurth Elektronik |
| C16 | 1 | 22 pF | CAP, CERM, 22 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0603 | 0603 | CGA3E2C0G1H220J080AA | TDK |
| C17, C18, C19, C20 | 4 | 2.2 µF | CAP, CERM, 2.2 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0805 | 0805 | CGA4J3X7R1H225K125AB | TDK |
| C21, C22 | 2 | 0.47 µF | CAP, CERM, 0.47 µF, 50 V, ±10%, X7R, AEC-Q200 Grade 1, 0603 | 0603 | CGA3E3X7R1H474K080AE | TDK |
| J1, J2, J3 | 3 | | Terminal Block, 5 mm, 2x1, Tin, TH | Terminal Block, 5 mm, 2x1, TH | 691 101 710 002 | Wurth Elektronik |
| J4 | 1 | | Header, 100 mil, 3x1, Gold, TH | Header, 100 mil, 3x1, TH | HTSW-103-07-G-S | Samtec |
| L1 | 1 | 4.7 µH | Inductor, Shielded, Hyperflux, 4.7 µH, 7.4 A, 0.0143 Ω, SMD | 6.65x6.45 mm | 74439346047 | Wurth Elektronik |
| L2 | 1 | | 1.2 µH Shielded Molded Inductor 7.5 A, 11.3 mΩ Max 2-SMD | SMD2 | 744316220 | Wurth Electronics |
| LBL1 | 1 | | | PCB Label 0.650 x 0.200 inch | THT-14-423-10 | Brady |
| R1, R6 | 2 | 1.00 k | RES, 1.00 k, 1%, 0.25 W, 1206 | 1206 | RC1206FR-071KL | Yageo America |
| R2 | 1 | 0 | RES, 0, 5%, 0.1 W, 0603 | 0603 | RC0603JR-070RL | Yageo |
| R3 | 1 | 33.2 k | RES, 33.2 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603 | 0603 | CRCW060333K2FKEA | Vishay-Dale |
| R4, R7 | 2 | 100 k | RES, 100 k, 1%, 0.1 W, 0603 | 0603 | RC0603FR-07100KL | Yageo |
| R5 | 1 | 100 | RES, 100, 1%, 0.1 W, 0603 | 0603 | RC0603FR-07100RL | Yageo |
| R8 | 1 | 24.9 k | RES, 24.9 k, 1%, 0.1 W, 0603 | 0603 | RC0603FR-0724K9L | Yageo |
| R9 | 1 | 1.00 k | RES, 1.00 k, 1%, 0.1 W, 0603 | 0603 | ERJ-3EKF1001V | Panasonic |
| R10 | 1 | 255 k | RES, 255 k, 1%, 0.1 W, 0603 | 0603 | RC0603FR-07255KL | Yageo |

### Table 3. LMQ61460EVM-400K EVM Bill of Materials (continued)

| DESIGNATOR | QUANTITY | VALUE | DESCRIPTION | PACKAGE REFERENCE | PART NUMBER | MANUFACTURER |
|---|---|---|---|---|---|---|
| SH-J1 | 1 | | Shunt, 100 mil, Gold plated, Black | Shunt 2 pos. 100 mil | 881545-2 | TE Connectivity |
| TP1, TP9 | 2 | | Test Point, Multipurpose, Red, TH | Red Multipurpose Testpoint | 5010 | Keystone |
| TP2, TP3, TP5, TP6 | 4 | | Test Point, Multipurpose, Black, TH | Black Multipurpose Testpoint | 5011 | Keystone |
| TP4, TP7 | 2 | | Test Point, Multipurpose, Orange, TH | Orange Multipurpose Testpoint | 5013 | Keystone |
| TP8, TP10 | 2 | | Test Point, Multipurpose, White, TH | White Multipurpose Testpoint | 5012 | Keystone |
| U1 | 1 | | Automotive 6-A Low Noise Synchronous Buck Regulators, RJR0014A (VQFN-HR-14) | RJR0014A | LMQ61460AASQRJRRQ1 | Texas Instruments |
| C10, C11 | 0 | 22 µF | CAP, CERM, 22 µF, 16 V, ±20%, X7R, AEC-Q200 Grade 1, 1210 | 1210 | CGA6P1X7R1C226M250AC | TDK |
| C14 | 0 | 1 µF | CAP, CERM, 1 µF, 10 V, ±10%, X7R, 0603 | 0603 | GRM188R71A105KA61D | MuRata |
| C23, C24 | 0 | 1 µF | CAP, CERM, 1 µF, 50 V, ±10%, X7R, 0603 | 0603 | UMK107AB7105KA-T | Taiyo Yuden |
| FID1, FID2, FID3, FID4, FID5, FID6 | 0 | | Fiducial mark. There is nothing to buy or mount. | N/A | N/A | N/A |
| R12 | 0 | 0.51 | RES, 0.51, 1%, 0.25 W, 0805 | 0805 | CRM0805-FX-R510ELF | Bourns |
| R13 | 0 | 100 k | RES, 100 k, 1%, 0.1 W, 0603 | 0603 | RC0603FR-07100KL | Yageo |

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