EVM User's Guide: LM72880QEVM-400

LM72880-Q1 CC-CV Buck Converter With I2C Evaluation Module

Description

The LM72880QEVM-400 evaluation module (EVM) is a synchronous, buck DC/DC regulator which is capable of constant-current constant-voltage (CC-CV) regulation with I2C interface. The EVM operates over a wide input voltage range of 24V to 70V (at J4 VIN terminal), providing maximum 5A in CC mode and maximum 20V in CV mode. The regulation targets of the average inductor current limit and the output voltage are programmable by I2C. The free-running switching frequency is also programmable by I2C and is synchronizable to an external clock signal at a higher or lower frequency.

Get Started

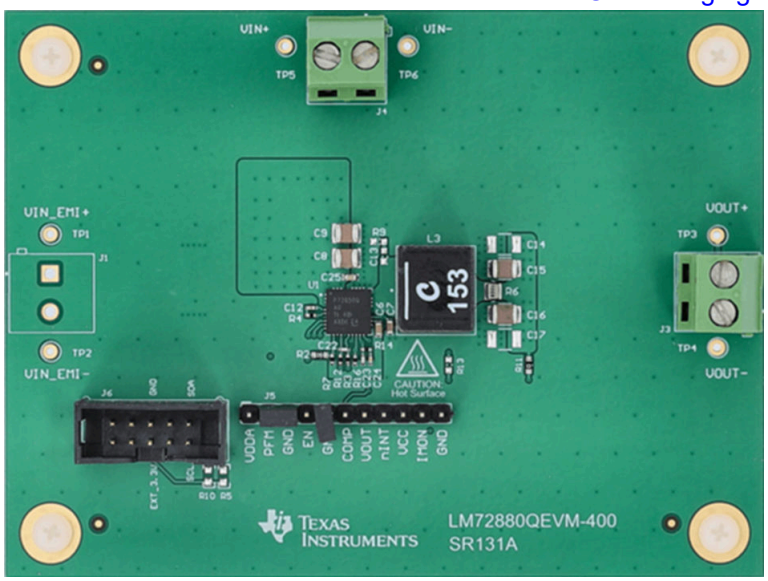
1. Connect the EVM to a power supply and a load.
2. Connect a USB2ANY adapter to the EVM and PC.
3. Launch the Configuration GUI in the product folder.

Features

- Input voltage operating range : 24V to 70V
- Programmable output voltage up to 20V with programmable cable drop compensation (CDC)
- Programmable average current limit up to 5A
- Programmable output voltage slew rate
- Programmable soft-start time
- Optional active output discharge
- Optional spread spectrum
- Programmable switching mode (FPWM or PFM)
- Peak full-load efficiency of 98.2%
- Peak current limit with hiccup mode protection
- Programmable OVP threshold
- Programmable UV/OV warning threshold
- nINT indicator with pullup resistor to VDDA
- Thermally efficient layout with 6-layer, 2oz PCB

Applications

- Automotive electronic systems
- Infotainment and cluster
- Automotive USB charging



LM72880QEVM-400

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1 Evaluation Module Overview

1.1 Introduction

The LM72880QEVM-400 EVM is a synchronous, buck DC/DC regulator with constant-current constant-voltage (CC-CV) regulation and I2C interface. The EVM operates over an input voltage range of 24V to 70V (VIN terminal), providing a regulated current of 5A (maximum) in CC mode and a regulated voltage of 20V (maximum) in CV mode. The regulation targets of the average inductor current limit and the output voltage are programmable by I2C. As a default, the output voltage is pre-programmed to 5V, the average inductor current limit is pre-programmed to 0.5A, and the free-running frequency is pre-programmed to 400kHz.

The EVM features cable drop compensation, spread spectrum, selectable FPWM/PFM, active output discharge, output slew rate control, soft start, OVP, and peak current limit with hiccup mode protection. The EVM is designed for 400kHz switching frequency.

1.2 Kit Contents

- One LM72880QEVM-400 EVM board
- EVM disclaimer Read Me

1.3 Specification

Table 1-1 table lists the electrical characteristics of the evaluation module. See the LM72880-Q1 product folder for more information about the device specifications. Efficiency and other performance metrics can change based on operating input voltage, load currents, externally-connected output capacitors, and other parameters. The recommended airflow is 200 LFM when operating.

Table 1-1. Electrical Performance Characteristics

Parameter	Test Conditions		MIN	TYP	MAX	Unit
INPUT CHARACTERISTICS						
Input operating range, V_{SUPPLY}	VIN+, VIN– terminal		24	48	70	V
Input current, I_{SUPPLY}					5	A
Input current, no load	PFM, BIAS_EN = 0, EN = VIN, V_{LOAD} = 20V, R7 removed, no I2C communication	V_{SUPPLY} = 24V		116		µA
		V_{SUPPLY} = 36V		116		
		V_{SUPPLY} = 48V		117		
		V_{SUPPLY} = 60V		119		
OUTPUT CHARACTERISTICS						
Rated output voltage, V_{LOAD}	CV mode			20		V
Average inductor current, I_{LOUT}	CC mode		0.5		5	A
SYSTEM CHARACTERISTICS						
Switching frequency, f_{SW}				400		kHz
Full load efficiency	I_{LOAD} = 5A	V_{SUPPLY} = 24V		98.2%		
		V_{SUPPLY} = 36V		97.7%		
		V_{SUPPLY} = 48V		97.1%		
		V_{SUPPLY} = 60V		96.6%		

1.4 Device Information

Table 1-2. LM72xx0(-Q1) Synchronous Buck Regulator Family With Integrated CC-CV Control and I2C Interface

DC/DC	Max VIN	Output Range	Max IOUT	Automotive Qualification
LM72630-Q1	70V	1V – 24V / 3.3V – 24V	3A	AEC-Q100 Grade1
LM72650-Q1	70V	1V – 24V / 3.3V – 24V	5A	AEC-Q100 Grade1
LM72680-Q1	70V	1V – 24V / 3.3V – 48V	5A / 8A	AEC-Q100 Grdae1
LM72880-Q1	80V	1V – 24V / 3.3V – 48V	5A / 8A	AEC-Q100 Grade1
LM72880	80V	1V – 24V / 3.3V – 48V	5A / 8A	—

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2 Hardware

2.1 Test Setup and Procedure

2.1.1 EVM Connections

The recommended test setup is shown in Figure 2-1. Working at an ESD-protected workstation, make sure that any wrist straps, boot straps, or mats are connected and referencing the user to earth ground before handling the EVM.

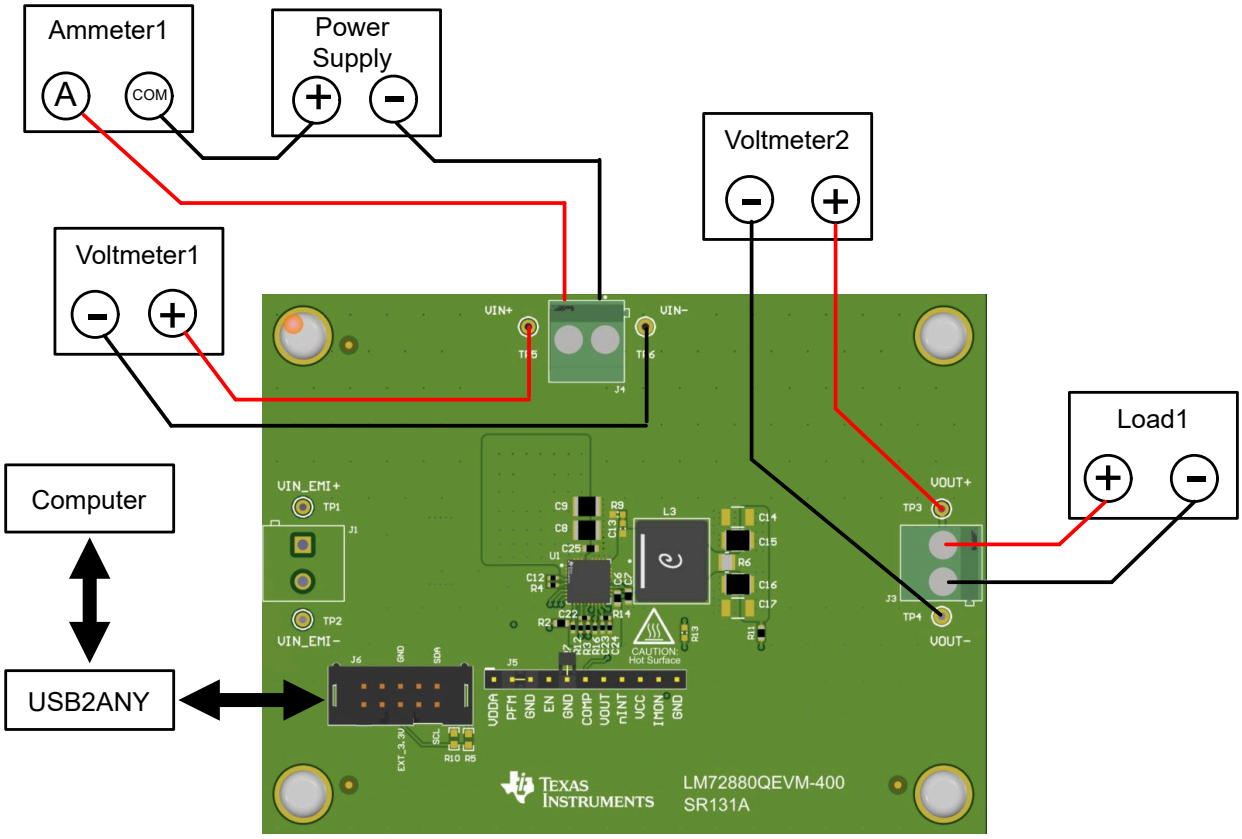

Figure 2-1. EVM Test Setup

CAUTION

Hot surface. Contact can cause burns. Do not touch.

Table 2-1. Power Connections

REF DES	LABEL	DESCRIPTION
J4	VIN+	Positive input voltage power connection
J4	VIN–	Negative input voltage power connection
J1	VIN_EMI+	Positive input voltage power connection for EMI test
J1	VIN_EMI–	Negative input voltage power connection for EMI test
J3	VOUT+	Positive output voltage power connection
J3	VOUT–	Negative output voltage power connection

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Table 2-2. DVM Connections

REF DES	LABEL	DESCRIPTION
TP5	VIN+	Positive input voltage sensing
TP6	VIN–	Negative input voltage sensing
TP3	VOUT+	Positive output voltage sensing
TP4	VOUT-	Negative output voltage sensing

Table 2-3. J5 Jumper

NUMBER	LABEL	DESCRIPTION
1	VDDA	VDDA connection
2	PFM	PFM / FPWM mode selection and synchronization input pin
3	GND	Ground connection
4	EN	Enable input. Connect the pin to GND to disable the device.
5	GND	Ground connection
6	COMP	External compensation pin
7	VOUT	VOUT connection pin
8	nINT	Interrupt indicator pin. An open-drain output is connected to VDDA through 100kΩ pullup resistor.
9	VCC	VCC connection
10	IMON	IMON connection. Current monitor pin. Leave the pin floating during start-up.
11	GND	Ground connection

Table 2-4. J6 Jumper

NUMBER	LABEL	DESCRIPTION
1, 2, 3, 4, 7, 8	NC	No connect pin
5	EXT-3.3V	Connected to the external 3.3V from USB2ANY
6	GND	Ground connection
9	SCL	I2C clock pin
10	SDA	I2C data pin

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2.1.2 Test Equipment

- **Power Supply:** use an input voltage source capable of supplying 0V to 70V and 7A.
- **Voltmeter 1:** measure the input voltage at VIN+ to VIN–.
- **Voltmeter 2:** measure the output voltage at VOUT+ to VOUT–.
- **Ammeter 1:** measure the input current. Connect to the power supply and VIN+.
- **Load 1:** the load must be an electronic load capable of constant-voltage (CV) and constant-current (CC) regulation. The electronic load must be capable of sinking 8A at 20V and below.

Oscilloscope: with the scope set to 20MHz bandwidth and AC coupling, measure the output voltage ripple directly across an output capacitor with a short ground lead normally provided with the scope probe. TI does not recommend using a long-leaded ground connection because this can induce additional noise given a large ground loop. To measure other waveforms, adjust the oscilloscope as needed. Always use caution when touching any circuits that can be live or energized.

2.1.3 Recommended Test Setup

Use the VIN+/TP5 and VIN–/TP6 test points along with the VOUT+/TP3, VOUT–/TP4 test points located near the power terminal blocks as voltage monitoring points where voltmeters are connected to measure the input and output voltages, respectively. *Do not use these sense terminals as the input supply or output load connection points.* The PCB traces connected to these sense terminals are not designed to support high currents. Before applying power to the EVM, make sure that the J5 jumper is present and properly positioned.

CAUTION

Extended operation at high output current and high input voltage can raise component temperatures above 55°C. To avoid risk of a burn injury, do not touch the components until the components have cooled sufficiently after disconnecting power. Wire gauge for the input power supply and the output electric load needs to be 9 AWG minimum and no longer than 1 foot. Please tighten the input and output terminal screws to minimize contact resistance.

2.1.3.1 Input Connections

1. Prior to connecting the input power source, set the current limit of the input supply to 0.1A maximum. Make sure the input source is initially set to 0V and connected to the J4 terminal as shown in Figure 2-1.
2. Connect voltmeter 1 at VIN+ and VIN– test points to measure the input voltage.
3. Connect ammeter 1 to measure the input current.

2.1.3.2 Output Connections

1. Connect electronic load to J3. Set the load to CV mode at 22V before applying input voltage.
2. Connect voltmeter 2 at VOUT+ and VOUT– test points to measure the output voltage.

2.1.3.3 I2C Connections

1. Plug 10-pin ribbon cable into the USB2ANY and J6.
2. Plug USB mini-B connector into the USB2ANY and the computer.

2.1.4 Test Procedure

2.1.4.1 Graphic User Interface (GUI)

2.1.4.1.1 Quick Overview

To start, connect the USB2ANY adapter to the computer using USB mini-B connector, connect the USB2ANY adapter to EVM using 10-pin ribbon cable, connect power supply and load to the EVM, power on the EVM, and then launch the configuration GUI.

The GUI automatically connects with the EVM, but if not, in the status bar at the bottom of the GUI, click the **Reconnect** button to connect to the EVM.

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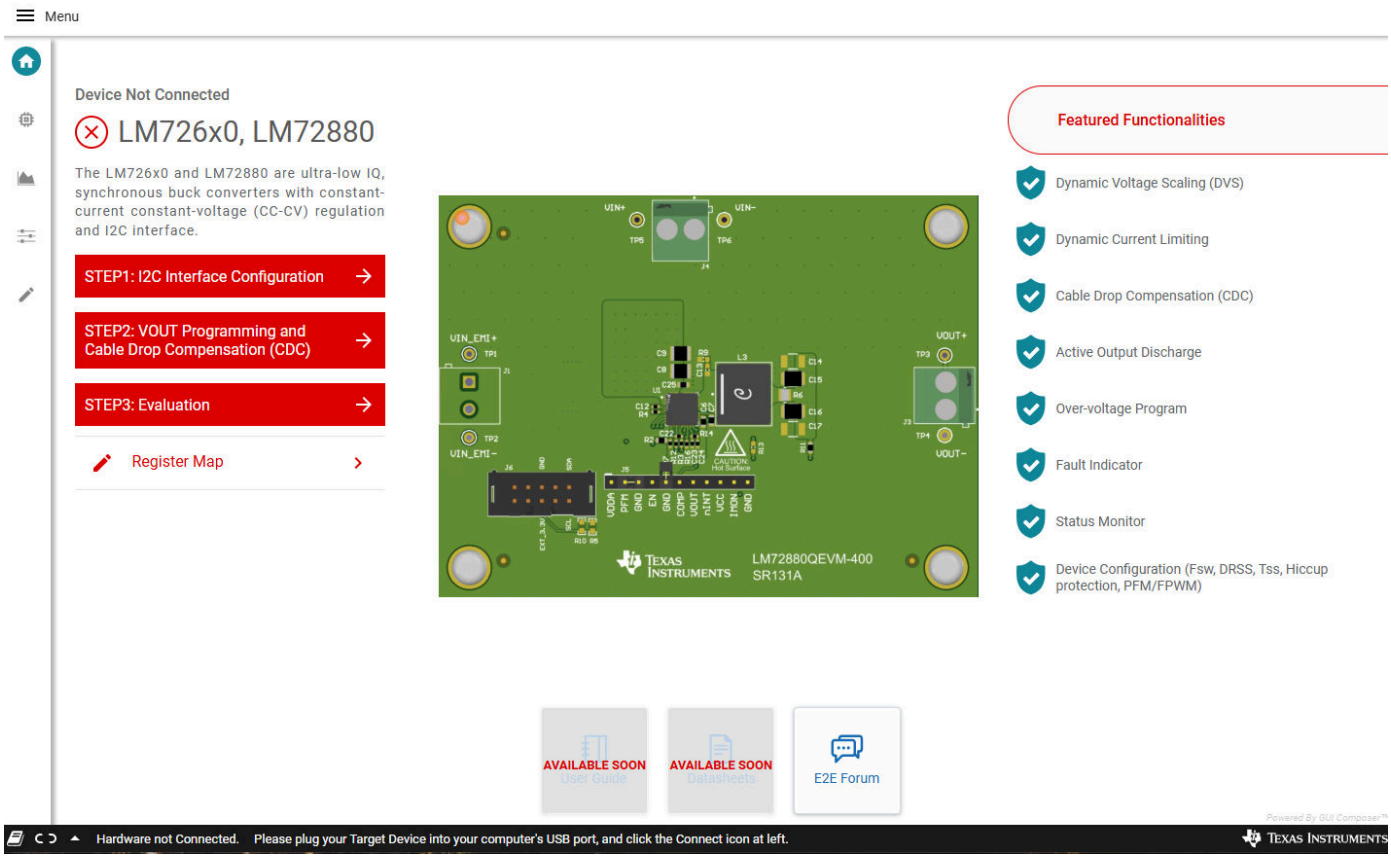

Figure 2-2. Get Started

Finish the I2C interface configuration in step 1 before programming the device. Select **LM72880** as the GPN and **8mΩ** as the sense resistor value. The device supports standard, fast, and fast-plus modes, but the GUI supports only standard and fast modes. Please select the standard mode as a starting point. Enable the pullup resistors inside the USB2ANY adapter and then click the **CONFIGURE USB2ANY** button. Select **0x6A** as the I2C target address, and then click the **CONNECT TO EVM** button.

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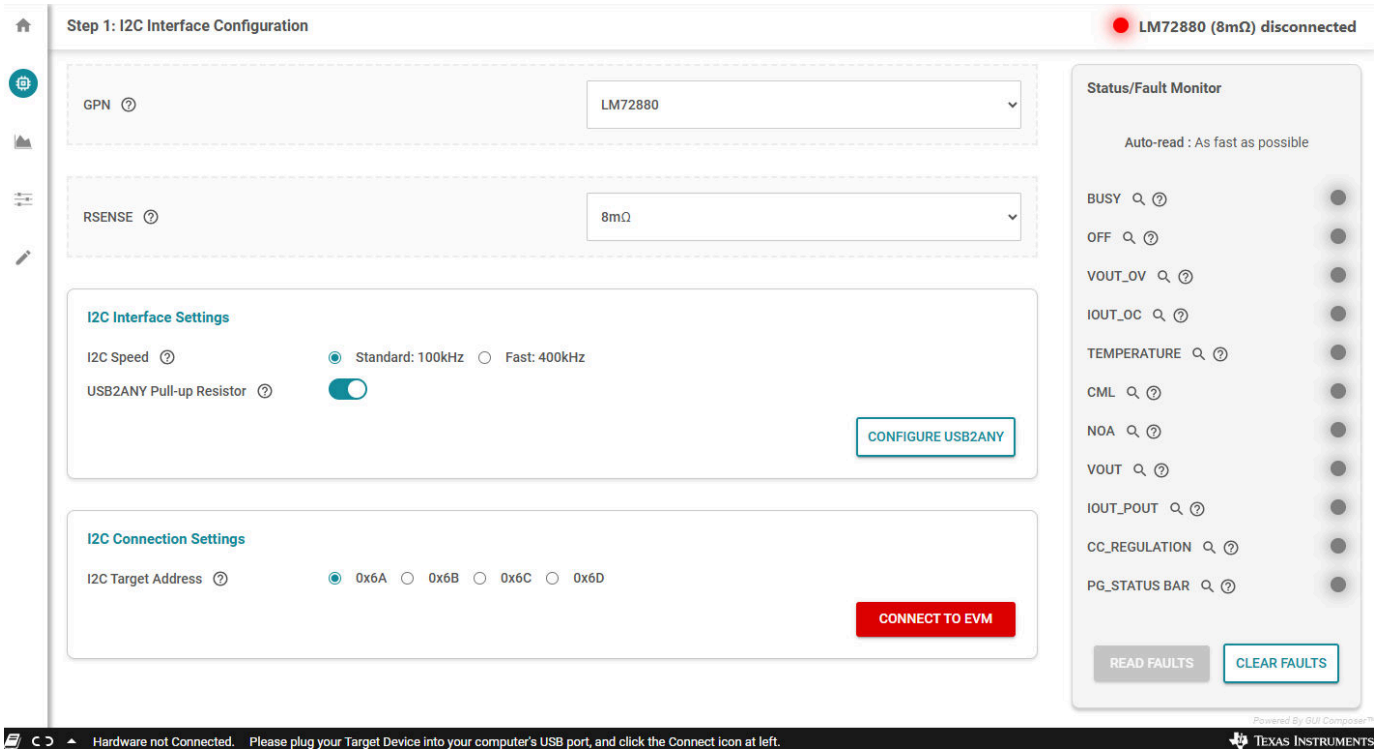

Figure 2-3. Step 1: I2C Interface Configuration

In step 2, program the VOUT regulation target to 20V as a starting point, and program the cable compensation gain if required.

Figure 2-4. Step 2: VOUT Programming and CDC

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Program the rest of the parameters in step 3, including switching frequency, spread spectrum, CC mode regulation target, OVP, PGOOD, DVS, and VOUT discharge. Program the CC mode regulation target to 5A and the switching frequency to 400kHz as a starting point. After finishing the device programming, the converter can be enabled by toggling on the **Enable Converter** toggle button when required.

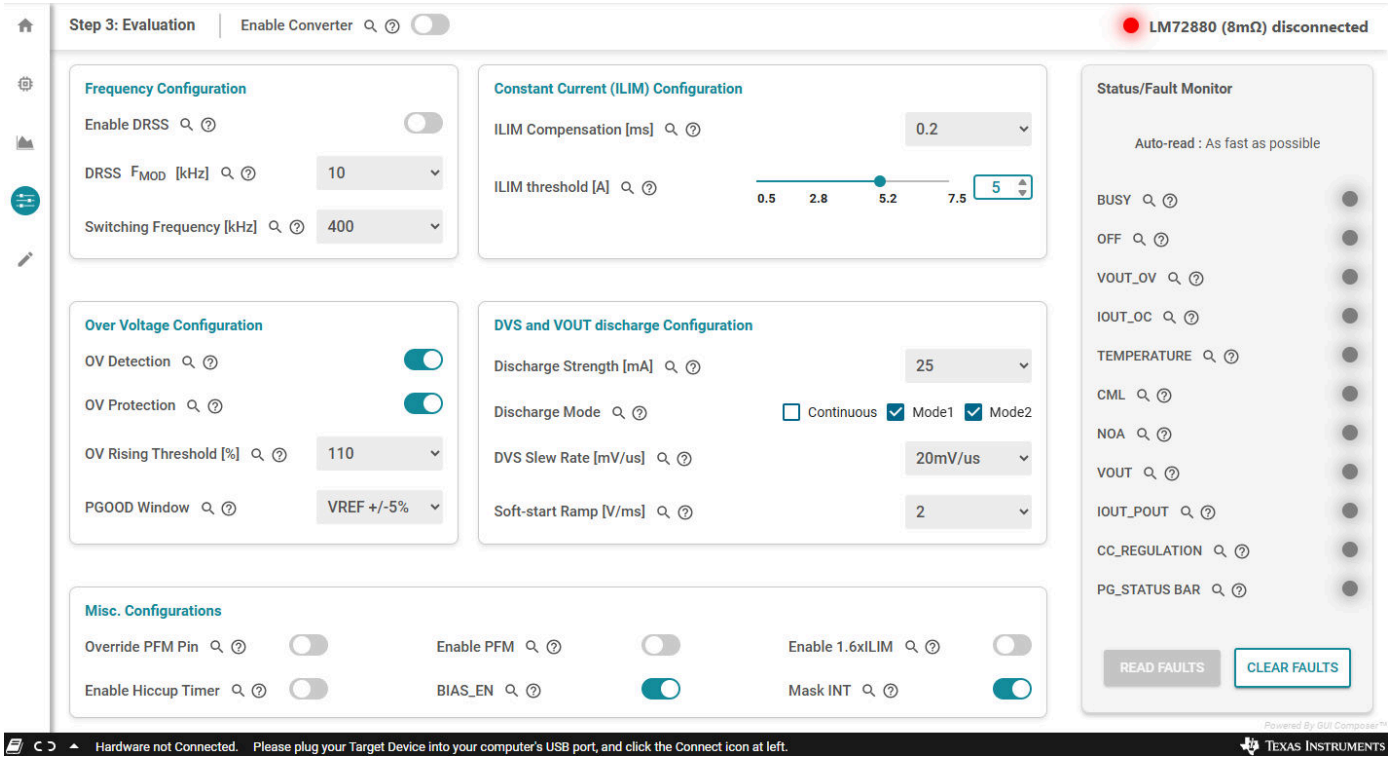

Figure 2-5. Step 3: Evaluation

Each I2C registers and bits can be monitored or programed in the register map. Please program the I2C register map directly if familiar with the device operation and the I2C interface.

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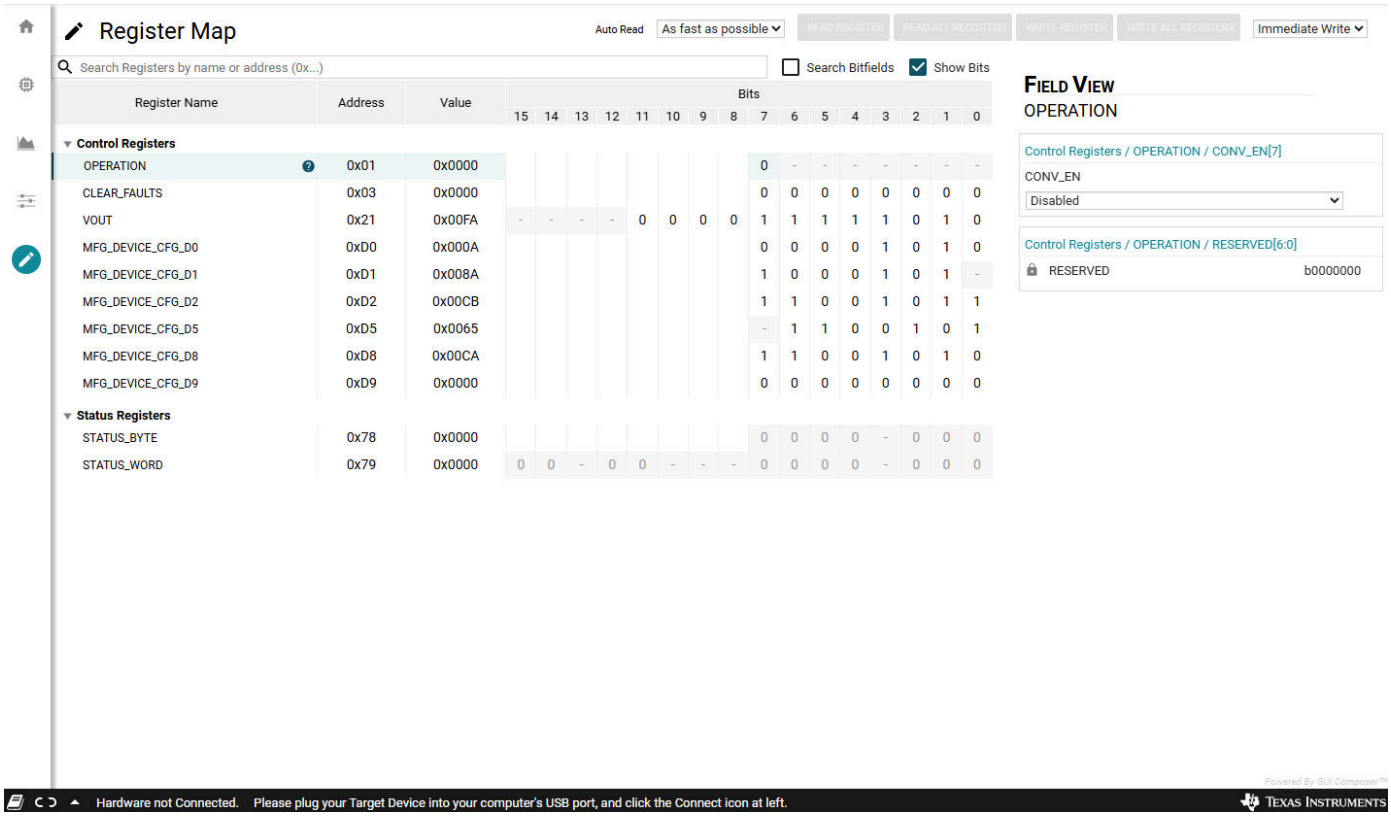

Figure 2-6. Register Map

2.1.4.2 Basic Test Procedure

1. Set up the EVM, USB2ANY, and Configuration GUI as previously described. *Do not enable the converter.*
2. Set the load to constant-voltage (CV) mode and set to 22V.
3. Set the current limit of the input supply to 0.1A maximum.
4. Set the input source 48V and turn on.
5. *Enable the converter by I2C*. The load voltage must be within the 20V regulation target.
6. Set the current limit of the input supply to 7A maximum.
7. Set the load voltage to 19V. The load current must be within the 5A regulation target.
8. Set the load voltage to 12V. The load current must be within the 5A regulation target.
9. Set the load voltage to 22V. The load voltage must be within the 20V regulation target and the load current must be 0A.
10. *Disable the Converter by I2C*.
11. Turn off the input power source.

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3 Implementation Results

3.1 Test Data and Performance Curves

Unless otherwise indicated, V_{SUPPLY} = 48V and f_{SW} = 400kHz

3.1.1 Efficiency

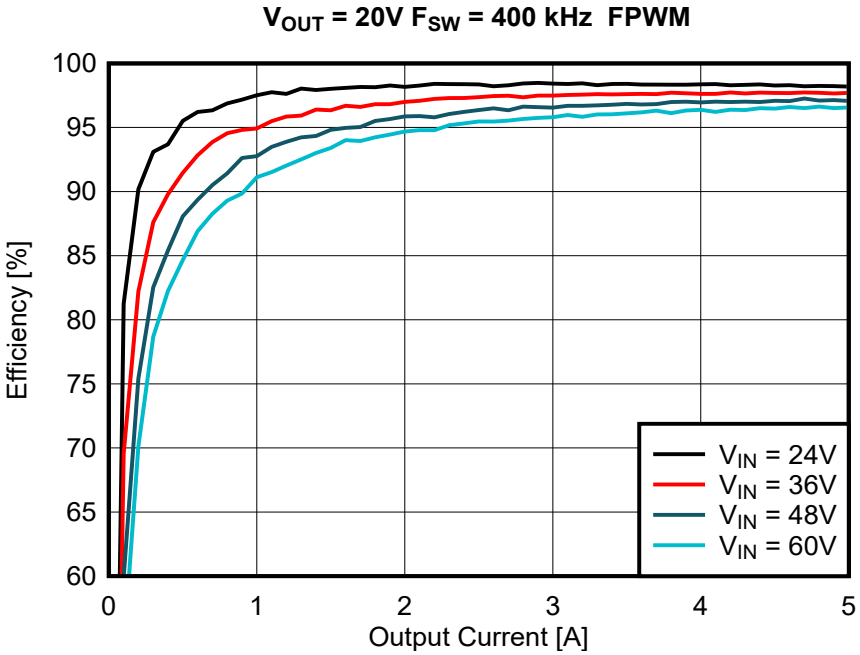

Figure 3-1. FPWM Mode, Linear Scale

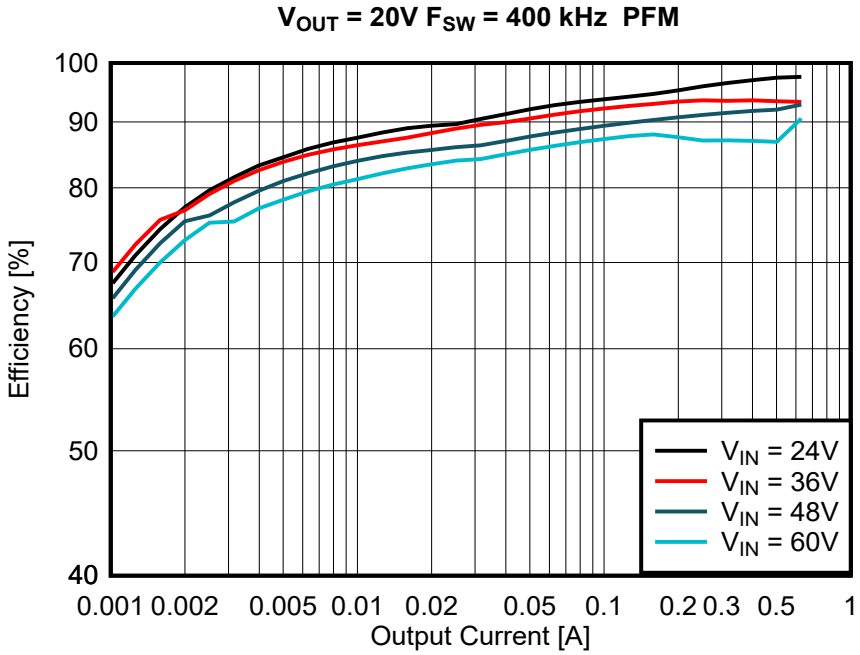

Figure 3-2. PFM Mode, Log Scale

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3.1.2 Operating Waveforms

3.1.2.1 Start-Up and Shutdown

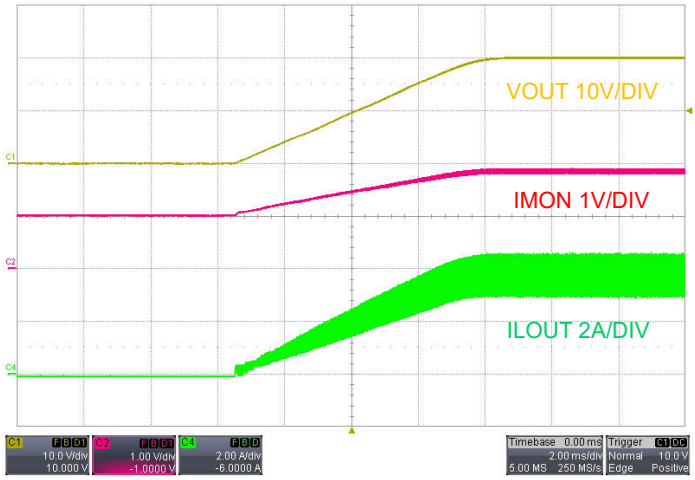

Figure 3-3. V_{SUPPLY} = 48V, I_{LOAD} = 4A Resistive Load

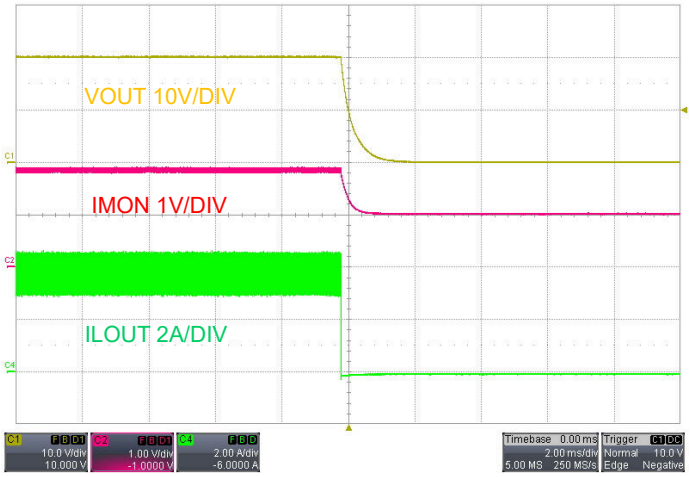

Figure 3-4. V_{SUPPLY} = 48V, I_{LOAD} = 4A Resistive Load

3.1.2.2 Switching

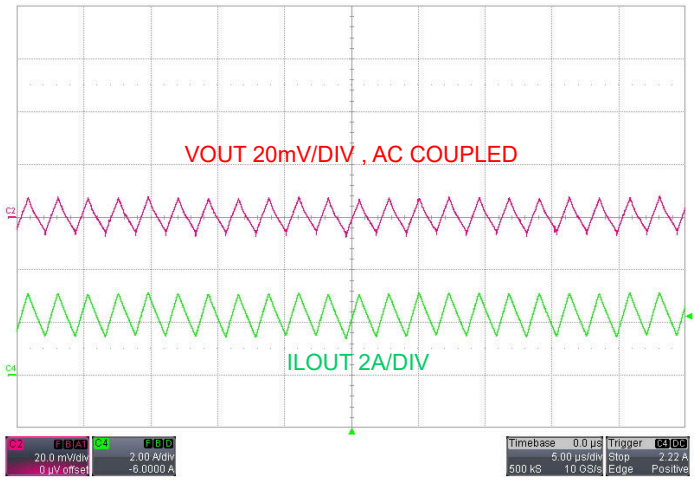

Figure 3-5. Output Ripple, V_{SUPPLY} = 48V, I_{LOAD} = 2A

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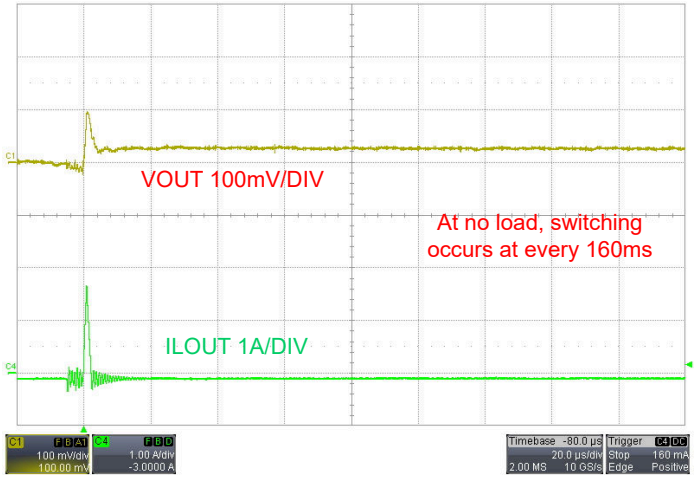

Figure 3-6. No Load Operation in PFM Mode, V_{SUPPLY} = 48V, I_{LOAD} = 0A

3.1.2.3 Load Transient (CV), ISET Modulation (CC)

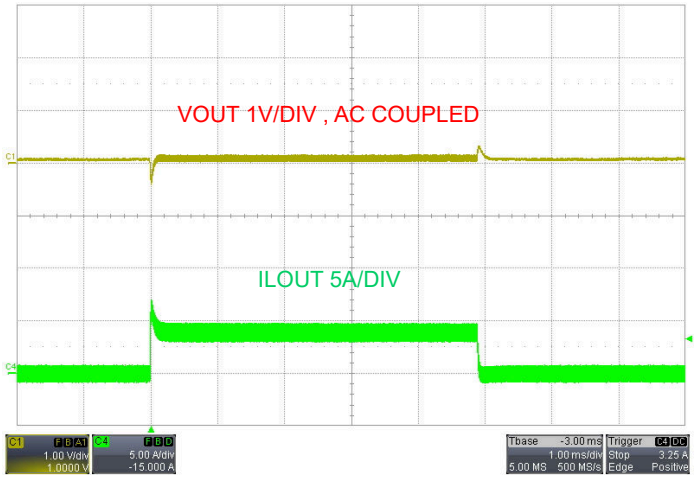

Figure 3-7. Load Transient Response, V_{SUPPLY} = 48V, FPWM, 0A to 4A

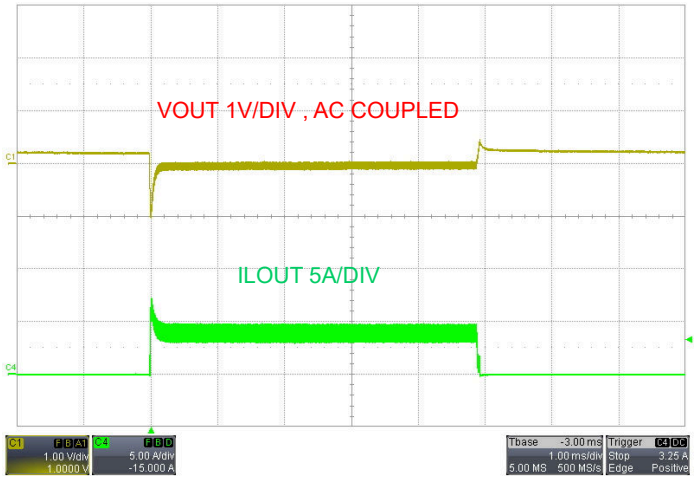

Figure 3-8. Load Transient Response, V_{SUPPLY} = 48V, PFM, 0A to 4A

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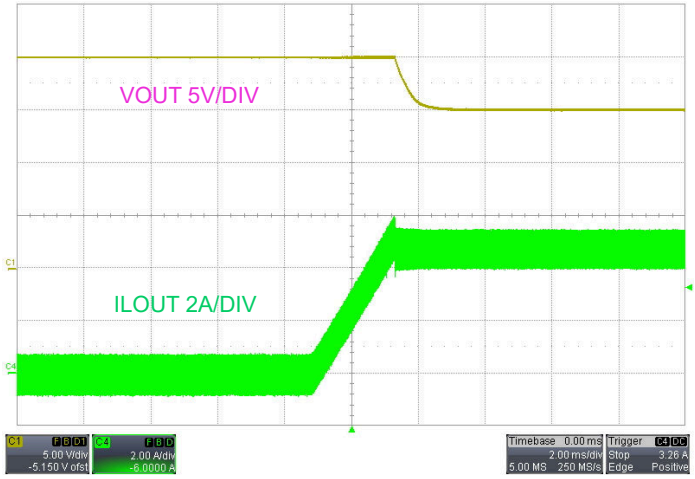

Figure 3-9. CV to CC mode Transition, V_{SUPPLY} = 48V, V_{LOAD} = 20V to 15V

3.1.3 Thermal Performance

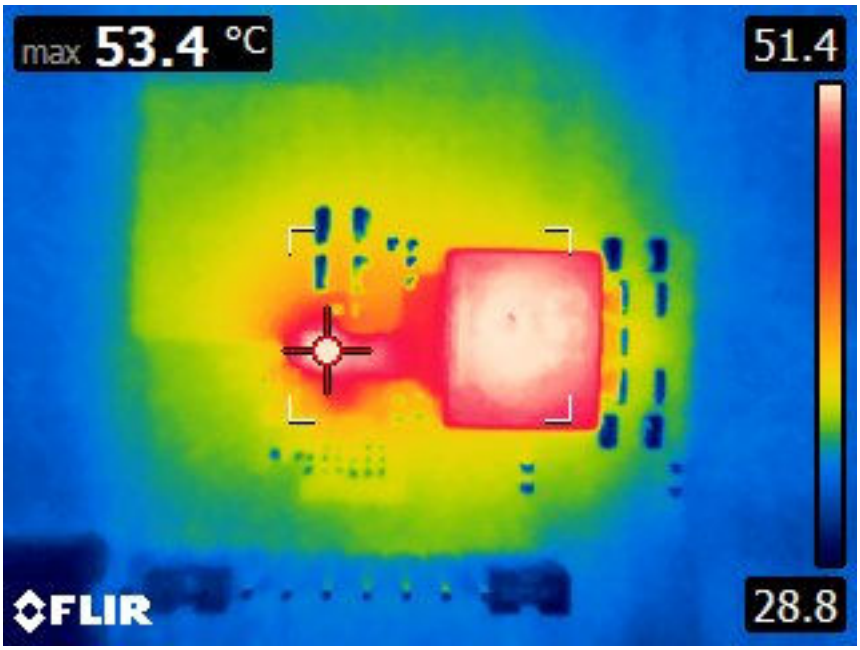

Figure 3-10. Thermal Performance, V_{SUPPLY} = 48V, V_{LOAD} = 20V, I_{LOAD} = 5A, T_A = 25°C, No Airflow

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3.1.4 EMI Performance

Populated EMI filter components during EMI test (L1 : XGL4040-222MEC, L2 : CM7060P701R-10).

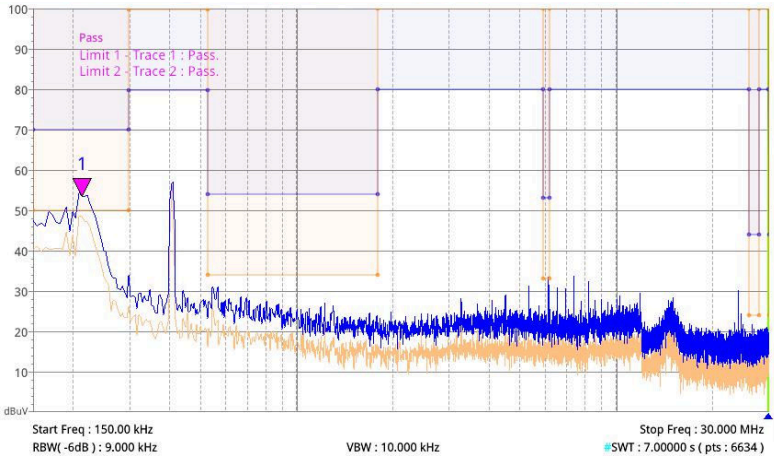

Figure 3-11. 150kHz to 30MHz, V_{SUPPLY} = 48V, V_{LOAD} = 20V, R_{LOAD} = 4Ω

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4 Hardware Design Files

4.1 Schematic

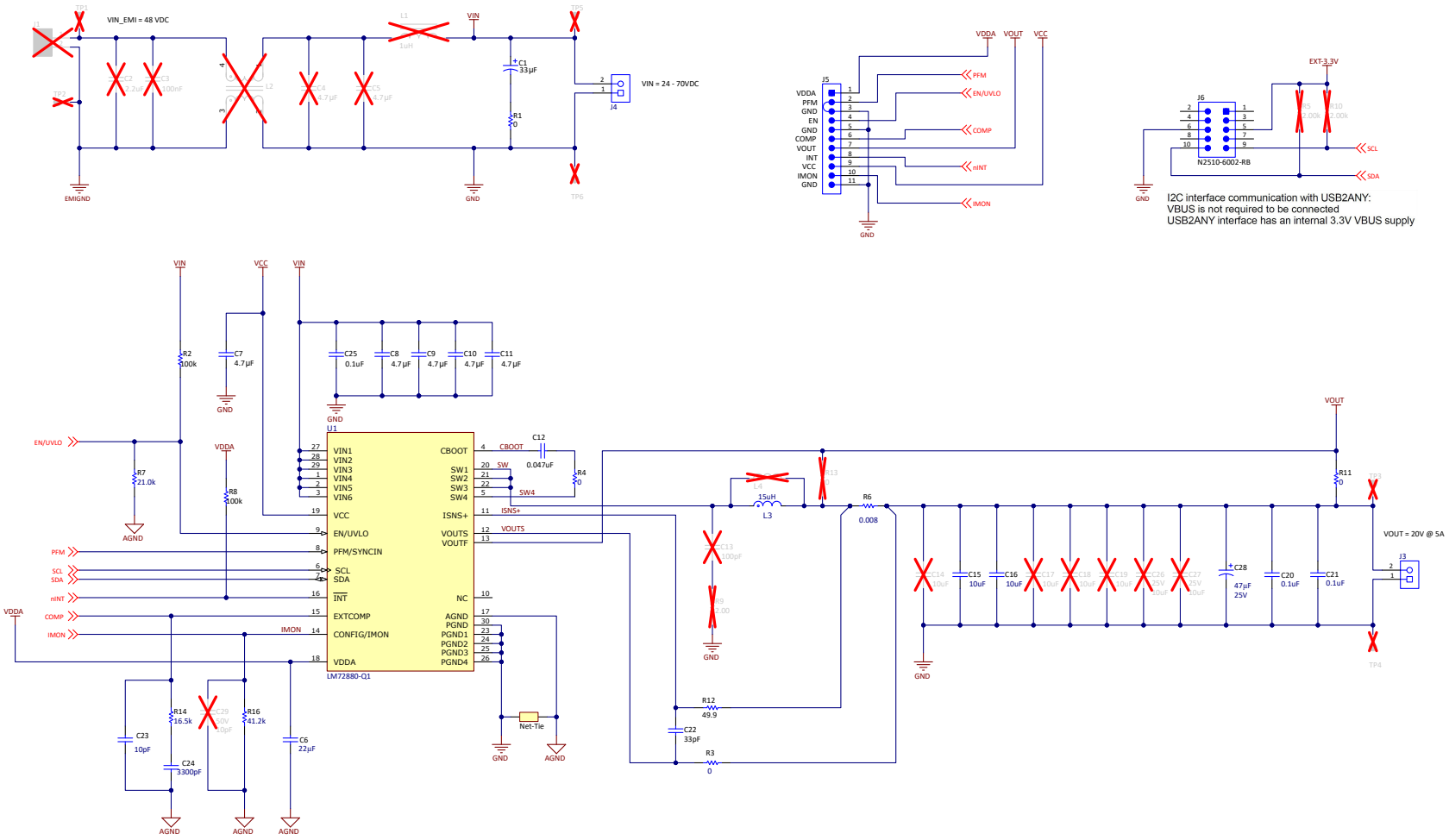

Figure 4-1. EVM Schematic

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4.2 PCB Layout

LM72880QEVM-400 uses a 6-layer PCB with 2oz copper thickness.

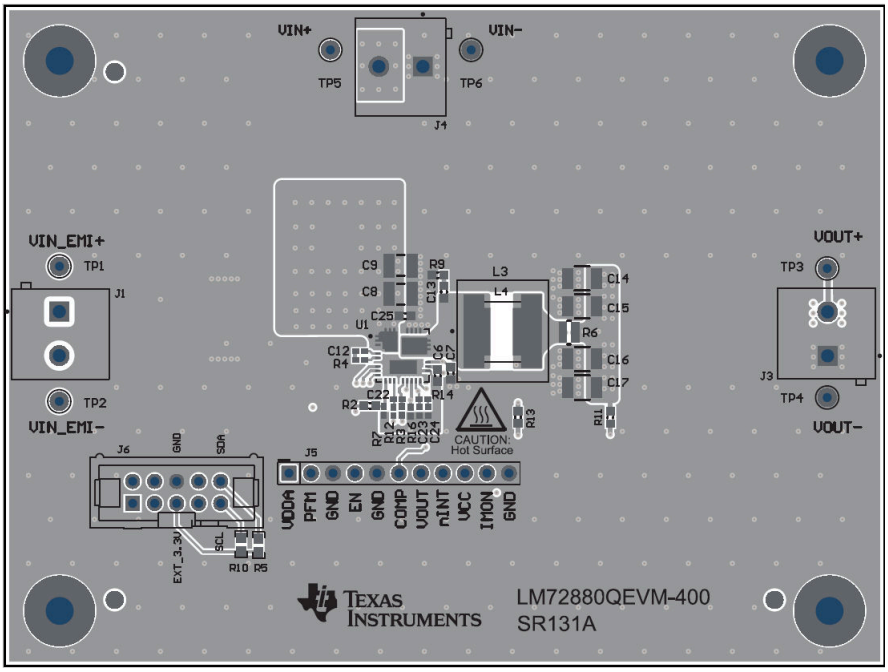

Figure 4-2. Top Components (Top View)

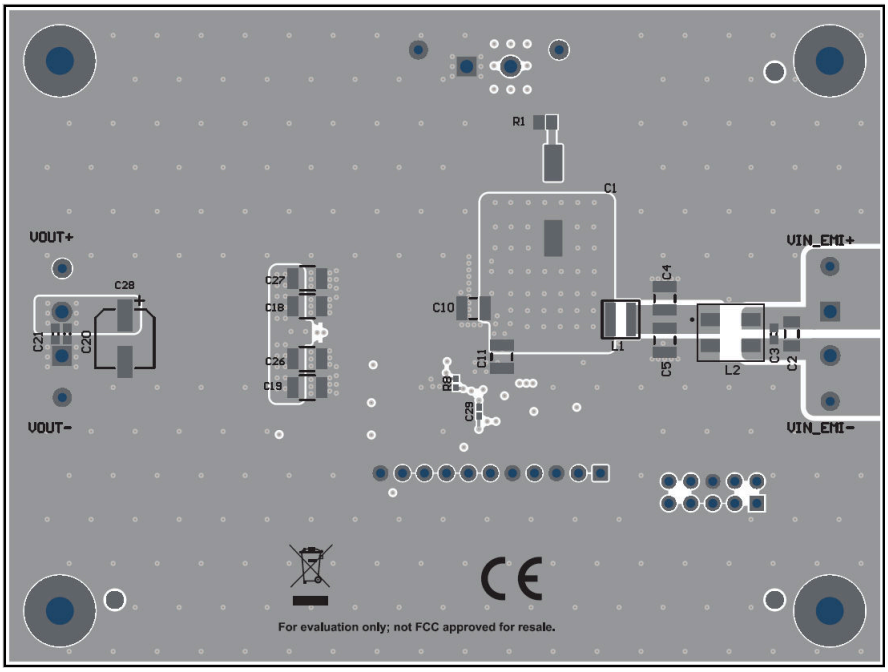

Figure 4-3. Bottom Components (Bottom View)

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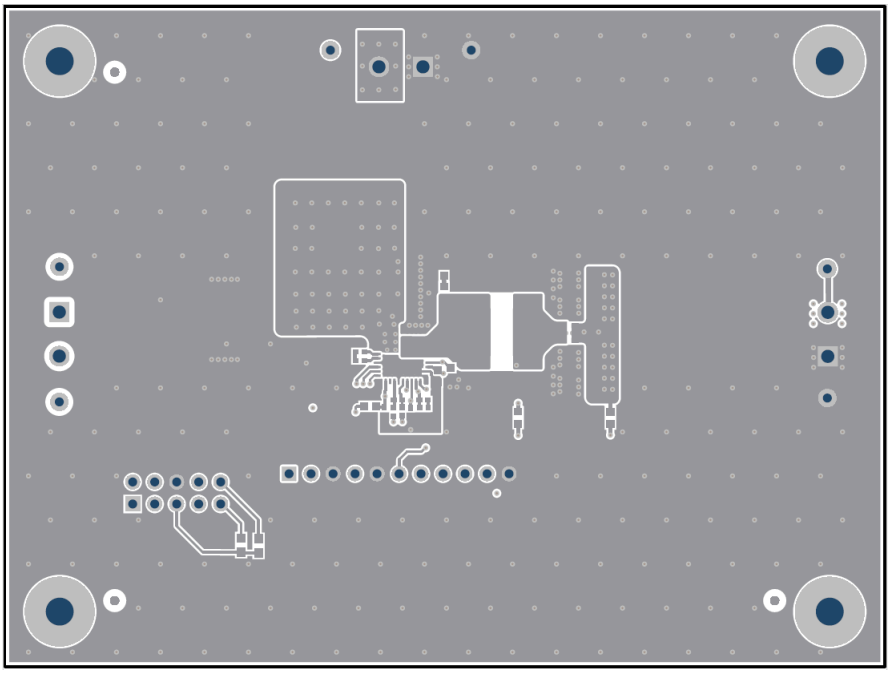

Figure 4-4. Top Layer Copper (Top View)

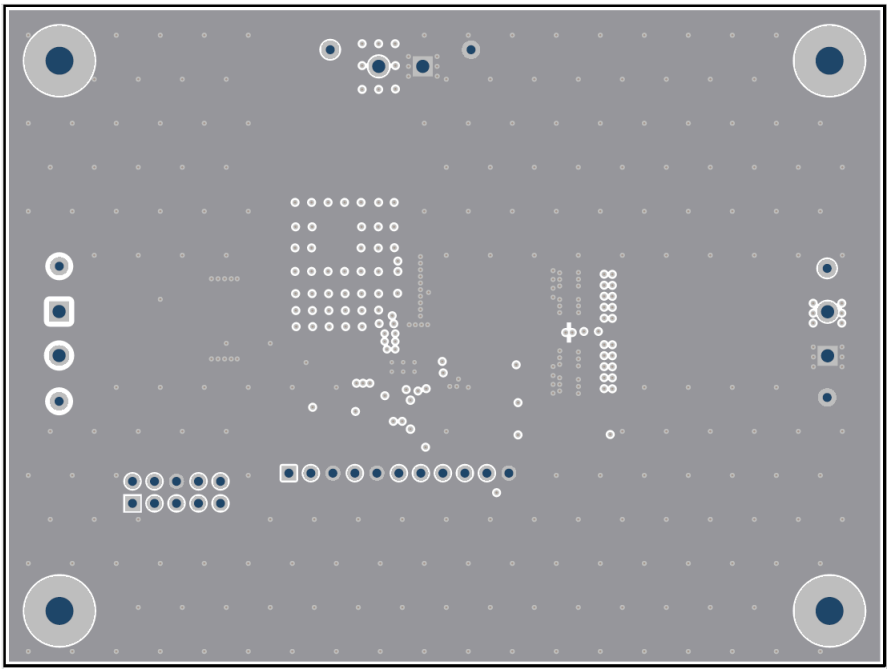

Figure 4-5. Layer 2 Copper (Top View)

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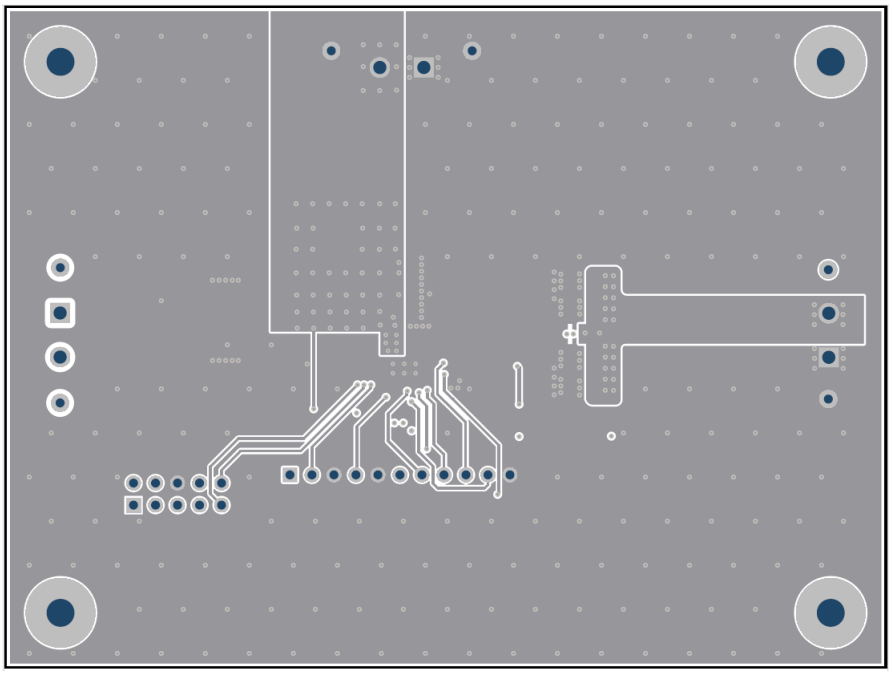

Figure 4-6. Layer 3 Copper (Top View)

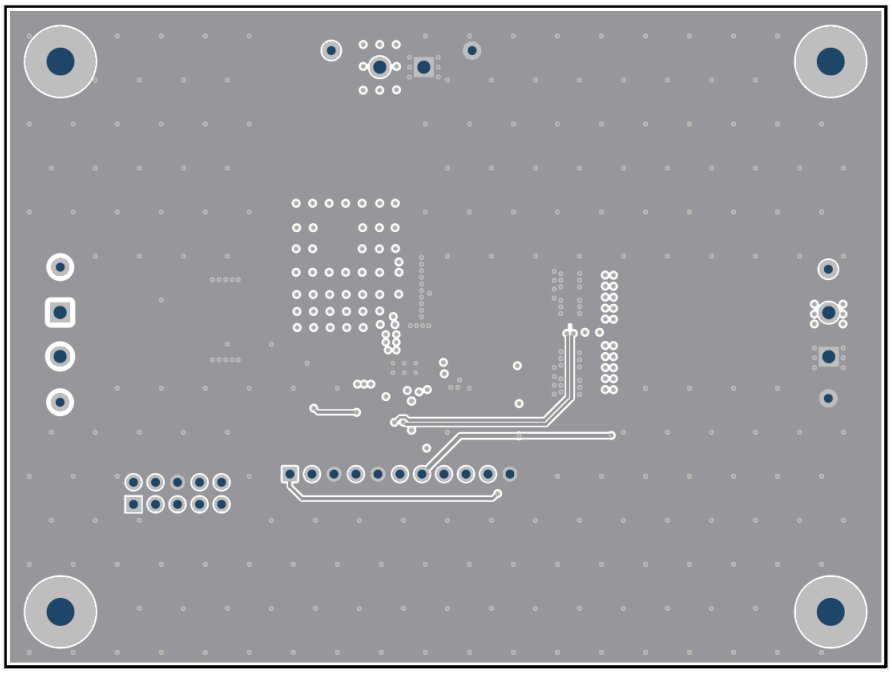

Figure 4-7. Layer 4 Copper (Top View)

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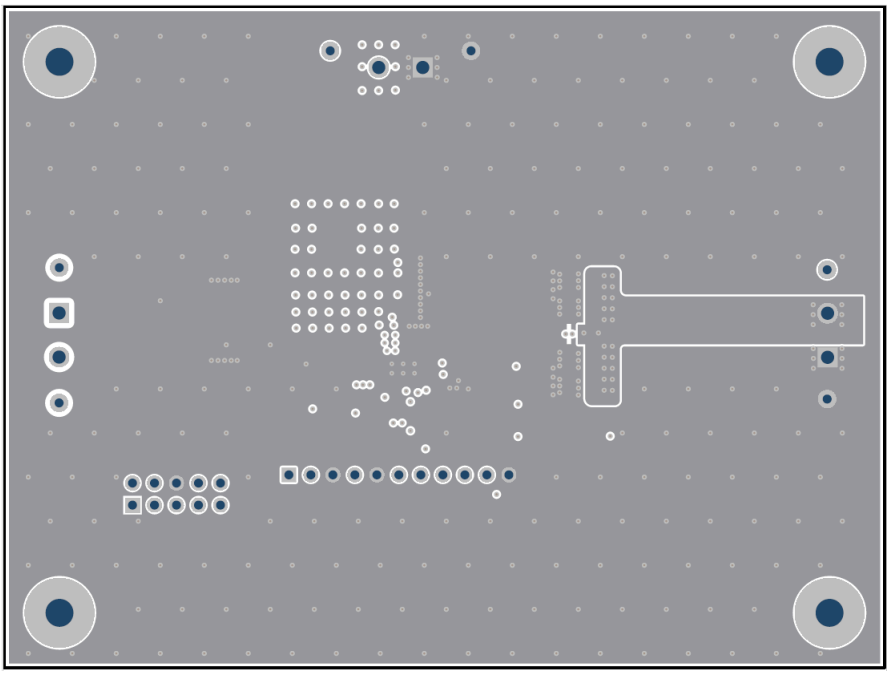

Figure 4-8. Layer 5 Copper (Top View)

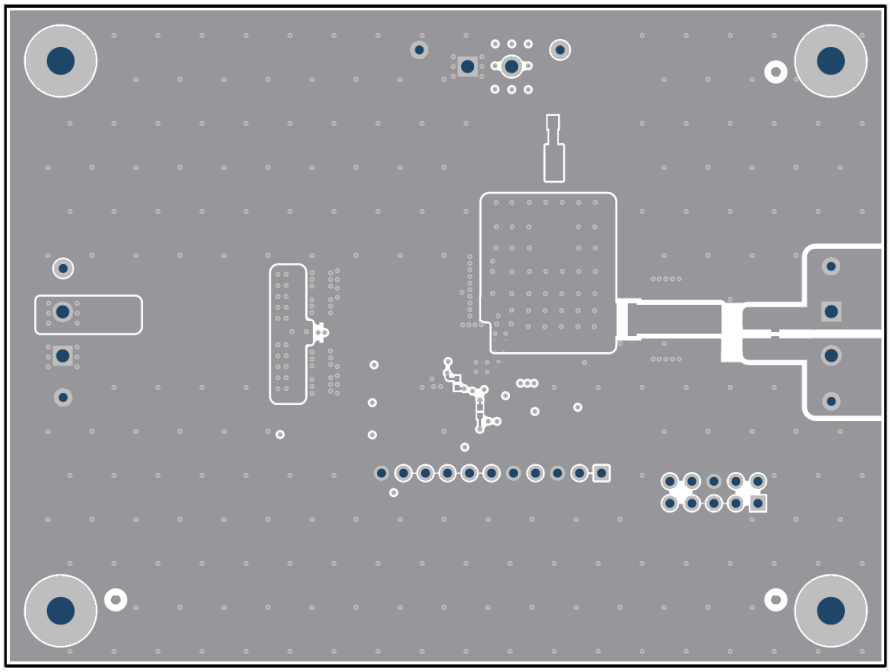

Figure 4-9. Bottom Copper (Bottom View)

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4.3 Bill of Materials

Table 4-1. Bill of Materials

QTY	REF DES	DESCRIPTION	PART NUMBER	MFR
1	C1	CAP, AL, 33µF, 100V, ±20%, 1 ohm, AEC-Q200 Grade 1, SMD	EEE-TG2A330P	Panasonic
1	C12	CAP, CERM, 0.047µF, 50V, ±10%, X7R, AEC-Q200 Grade 1, 0402	CGA2B3X7R1H473K050BB	TDK
2	C15, C16	CAP, CERM, 10µF, 25V, ±20%, X7R, AEC-Q200 Grade 1, 1210	CGA6P1X7R1E106M250AC	TDK
2	C20, C21	CAP, CERM, 0.1µF, 50V, ±10%, X7R, AEC-Q200 Grade 1, 0603	CGA3E2X7R1H104K080AA	TDK
1	C22	CAP, CERM, 33pF, 50V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0402	GCM1555C1H330JA16D	MuRata
1	C23	CAP, CERM, 10pF, 50V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0402	CGA2B2C0G1H100D050BA	TDK
1	C24	CAP, CERM, 3300pF, 50V, ±10%, X7R, AEC-Q200 Grade 1, 0402	CGA2B2X7R1H332K050BA	TDK
1	C25	CAP, CERM, 0.1µF, 100V, ±10%, X7R, AEC-Q200 Grade 1, 0603	GCJ188R72A104KA01D	MuRata
1	C28	CAP, AL, 47µF, 25V, +/– 20%, 0.05 ohm, AEC-Q200 Grade 1, SMD	HHXC250ARA470MF61G	Chemi-Con
1	C6	CAP, CERM, 22µF, 6.3V, ±20%, X6S, 0603	GRM188C80J226ME15D	MuRata
1	C7	CAP, CERM, 4.7µF, 10V, ±20%, X7R, 0603	GRM188Z71A475ME15D	MuRata
4	C8, C9, C10, C11	CAP, CERM, 47µF, 100V, ±10%, X7S, AEC-Q200 Grade 1, 1210	GCM32DC72A475KE02L	MuRata
4	H1, H2, H3, H4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
4	H5, H6, H7, H8	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
2	J3, J4	2 Position Wire to Board Terminal Block Horizontal with Board 0.200" (5.08mm) Through Hole	6.91254E+11	Wurth Electronics
1	J5	Header, 100mil, 11x1, Gold, TH	TSW-111-07-G-S	Samtec
1	J6	Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	N2510-6002-RB	3M
1	L3	15µH Shielded Molded Inductor 15.4A 15.2mOhm Max Nonstandard	XGL1010-153MED	Coilcraft
1	R1	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	ERJ-6GEY0R00V	Panasonic
1	R11	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL	Yageo
1	R12	RES, 49.9, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040249R9FKED	Vishay-Dale
1	R14	RES, 16.5 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040216K5FKED	Vishay-Dale
1	R16	RES, 41.2 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040241K2FKED	Vishay-Dale
1	R2	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603100KFKEA	Vishay-Dale
2	R3, R4	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale
1	R6	RES, 0.008, 1%, 1 W, AEC-Q200 Grade 0, 0508	KRL2012M-R008-F-T1	Susumu Co Ltd
1	R7	RES, 21.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040221K0FKED	Vishay-Dale
1	R8	RES, 100 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	RMCF0402FT100K	Stackpole Electronics Inc
2	SH-J1, SH-J2	Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
1	U1	80V, Synchronous CC-CV Buck Converter with I2C Interface	LM72880-Q1	Texas Instruments

5 Additional Information

5.1 Trademarks

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6 Device and Documentation Support

6.1 Device Support

6.1.1 Development Support

For development support, see the following:

- For TI's reference design library, visit TI reference designs.
- For TI's WEBENCH® Design Environments, visit the WEBENCH® Design Center.

6.2 Documentation Support

6.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *Improve High-current DC/DC Regulator Performance for Free with Optimized Power Stage Layout* application brief
- Texas Instruments, *Reduce Buck Converter EMI and Voltage Stress by Minimizing Inductive Parasitics* analog applications journal
- Texas Instruments, *AN-2162 Simple Success with Conducted EMI from DC-DC Converters* application note
- White papers:
  - Texas Instruments, *Valuing Wide V_{IN}, Low EMI Synchronous Buck Circuits for Cost-driven, Demanding Applications*
  - Texas Instruments, *An Overview of Conducted EMI Specifications for Power Supplies*
  - Texas Instruments, *An Overview of Radiated EMI Specifications for Power Supplies*

6.2.1.1 PCB Layout Resources

- Texas Instruments, *AN-1149 Layout Guidelines for Switching Power Supplies* application note
- Texas Instruments, *AN-1229 Simple Switcher PCB Layout Guidelines* application note
- Texas Instruments, *Constructing Your Power Supply – Layout Considerations Power Supply* design seminar
- Texas Instruments, *Low Radiated EMI Layout Made SIMPLE with LM4360x and LM4600x* application note

6.2.1.2 Thermal Design Resources

- Texas Instruments, *AN-2020 Thermal Design by Insight, Not Hindsight* application note
- Texas Instruments, *AN-1520 A Guide to Board Layout for Best Thermal Resistance for Exposed Pad Packages* application note
- Texas Instruments, *Semiconductor and IC Package Thermal Metrics* application note
- Texas Instruments, *Thermal Design Made Simple with LM43603 and LM43602* application note
- Texas Instruments, *PowerPAD™ Thermally Enhanced Package* application note
- Texas Instruments, *PowerPAD™ Made Easy* application brief
- Texas Instruments, *Using New Thermal Metrics* application note

7 Revision History

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

Changes from Revision * (April 2025) to Revision A (June 2025)	Page
• Updated board image	1
• Updated output ripple waveform in Section 3.1.2.2	11
• Added IR image in Section 3.1.3	13
• Added EMI test result in Section 3.1.4	14

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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.

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2. 実験局の免許を取得後ご使用いただく。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

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