EVM User's Guide: LM5192QEVM-400

LM5192-Q1 CC-CV Buck Controller With I^{2}C Evaluation Module

Description

The LM5192QEVM-400 EVM is a synchronous, buck regulator which is capable of constant-current constant-voltage regulation with I^{2}C interface. The EVM operates over an input voltage range of 15V to 70V, providing maximum 8A in CC mode and maximum 12V in CV mode.

Get Started

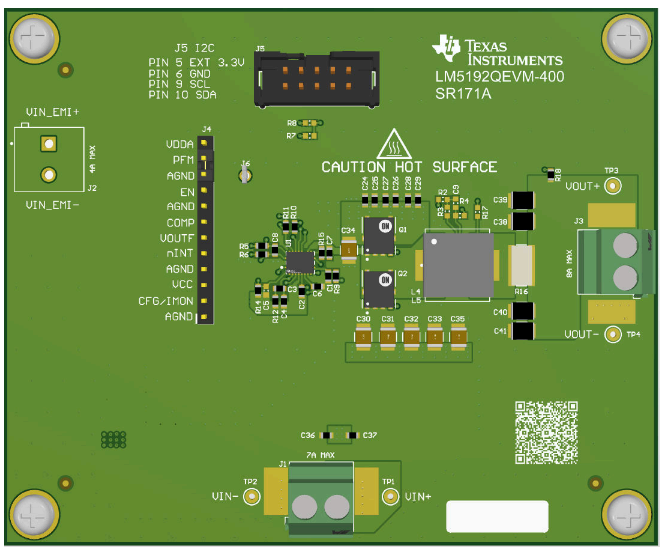
1. Connect the EVM to a power supply and a load.
2. Connect a USB2ANY adapter to the EVM and PC.
3. Launch the Configuration GUI in the product folder.

Features

- Input voltage operating range: 15V to 70V (at J1 VIN terminal)
- Programmable output voltage up to 12V with programmable cable drop compensation (CDC)
- Programmable average current limit up to 8A
- Peak full-load efficiency of 96% at V_{SUPPLY} = 48V
- Thermally efficient layout with 6-layer, 2oz PCB

Applications

- Automotive lighting
- Infotainment and cluster
- Automotive USB charging



LM5192QEVM-400

1 Evaluation Module Overview

1.1 Introduction

The LM5192QEVM-400 EVM is a synchronous, buck DC/DC regulator with constant-current constant-voltage (CC-CV) regulation and I^2C interface. The EVM operates over an input voltage range of 15V to 70V (VIN terminal), providing a regulated current of 8A (maximum) in CC mode and a regulated voltage of 12V (maximum) in CV mode. The regulation targets of the average inductor current limit and the output voltage are programmable by I^2C. 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 LM5192QEVM-400 EVM board
- EVM disclaimer Read Me

1.3 Specification

Table 1-1 table lists the electrical characteristics of the evaluation module. See the LM5192-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		15	48	70	V
Input current, I_{SUPPLY}					8	A
Input current, no load	PFM, BIAS_EN = 1, EN = VIN, V_{LOAD} = 12V, R11 removed, no I^2C communication	V_{SUPPLY} = 24V		195		μA
		V_{SUPPLY} = 48V		105		
		V_{SUPPLY} = 60V		88		
OUTPUT CHARACTERISTICS						
Rated output voltage, V_{LOAD}	CV mode			12		V
Average inductor current, I_{LOUT}	CC mode				8	A
SYSTEM CHARACTERISTICS						
Switching frequency, f_{SW}				400		kHz
Full load efficiency	I_{LOAD} = 8A	V_{SUPPLY} = 24V		97.1%		
		V_{SUPPLY} = 48V		96.0%		
		V_{SUPPLY} = 60V		95.5%		

1.4 Device Information

Table 1-2. LM(2)5192(-Q1) Synchronous Buck Controller Family With Integrated CC-CV Control and I^2C Interface

DC/DC	MAX VIN	OUTPUT RANGE	AUTOMOTIVE QUALIFICATION
LM5192-Q1	80V	1V – 24V / 3.3V – 48V	AEC-Q100 Grade1
LM25192-Q1	42V	1V – 24V / 3.3V – 24V	AEC-Q100 Grade1
LM5192	80V	1V – 24V / 3.3V – 48V	Commercial

2 Hardware

2.1 Test Setup and Procedure

2.1.1 EVM Connections

Figure 2-1 shows the recommended test setup. 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.

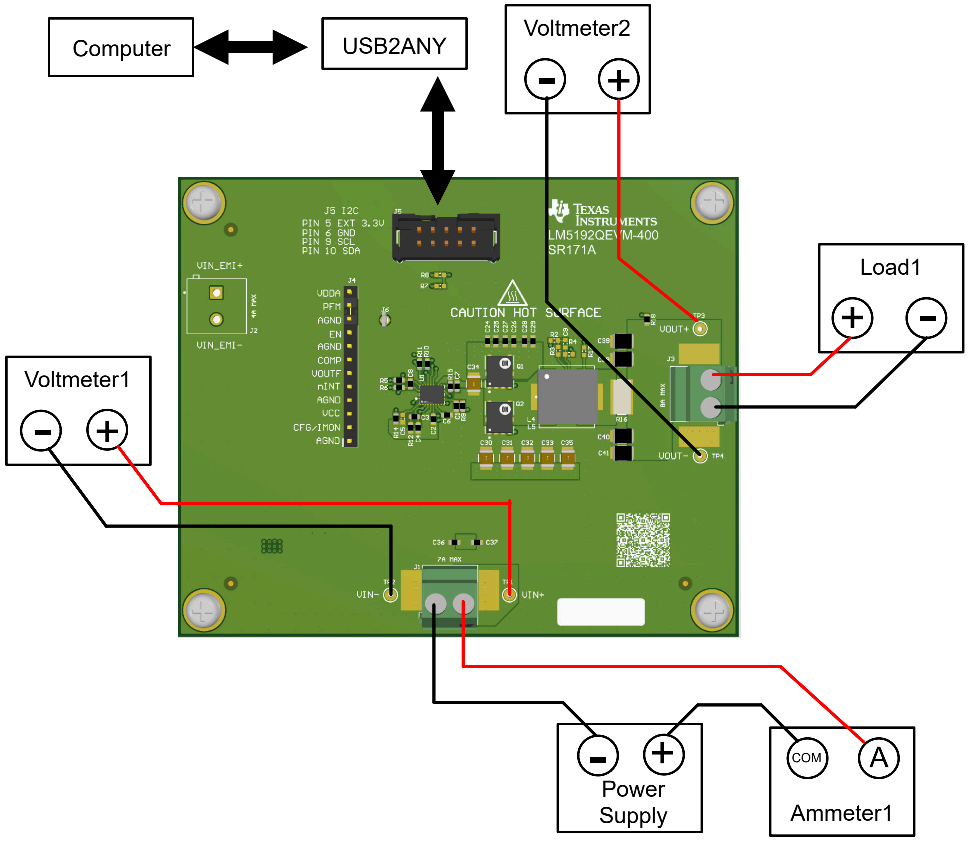


Figure 2-1. EVM Test Setup

CAUTION

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

Table 2-1. Power Connections

REF DES	LABEL	DESCRIPTION
J1	VIN+	Positive input voltage power connection
J1	VIN–	Negative input voltage power connection
J2	VIN_EMI+	Positive input voltage power connection for EMI test
J2	VIN_EMI–	Negative input voltage power connection for EMI test
J3	VOUT+	Positive output voltage power connection
J3	VOUT–	Negative output voltage power connection

Table 2-2. DVM Connections

REF DES	LABEL	DESCRIPTION
TP1	VIN+	Positive input voltage sensing
TP2	VIN–	Negative input voltage sensing
TP3	VOUT+	Positive output voltage sensing
TP4	VOUT-	Negative output voltage sensing

Table 2-3. J4 Jumper

NUMBER	LABEL	DESCRIPTION
12	VDDA	VDDA connection
11	PFM	PFM / FPWM mode selection and synchronization input pin
10	AGND	Ground connection
9	EN	Enable input. Connect the pin to GND to disable the device.
8	AGND	Ground connection
7	COMP	External compensation pin
6	VOUTF	VOUTF connection pin
5	nINT	Interrupt indicator pin.
4	AGND	Ground connection
3	VCC	VCC connection
4	CFG/IMON	IMON connection. Current monitor pin. Leave the pin floating during start-up.
1	AGND	Ground connection

Table 2-4. J5 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	I^2C clock pin
10	SDA	I^2C data pin

2.1.2 Test Equipment

- **Power Supply:** use an input voltage source capable of supplying 0V to 70V and 10A.
- **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 10A at 12V 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+/TP1 and VIN–/TP2 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 J4 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 J1 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 14V before applying input voltage.
2. Connect voltmeter 2 at VOUT+ and VOUT– test points to measure the output voltage.

2.1.3.3 I^{2}C Connections

1. Plug the 10-pin ribbon cable into the USB2ANY and J5.
2. Plug the 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 the EVM using a 10-pin ribbon cable, connect the 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, select the *Reconnect* button to connect to the EVM.

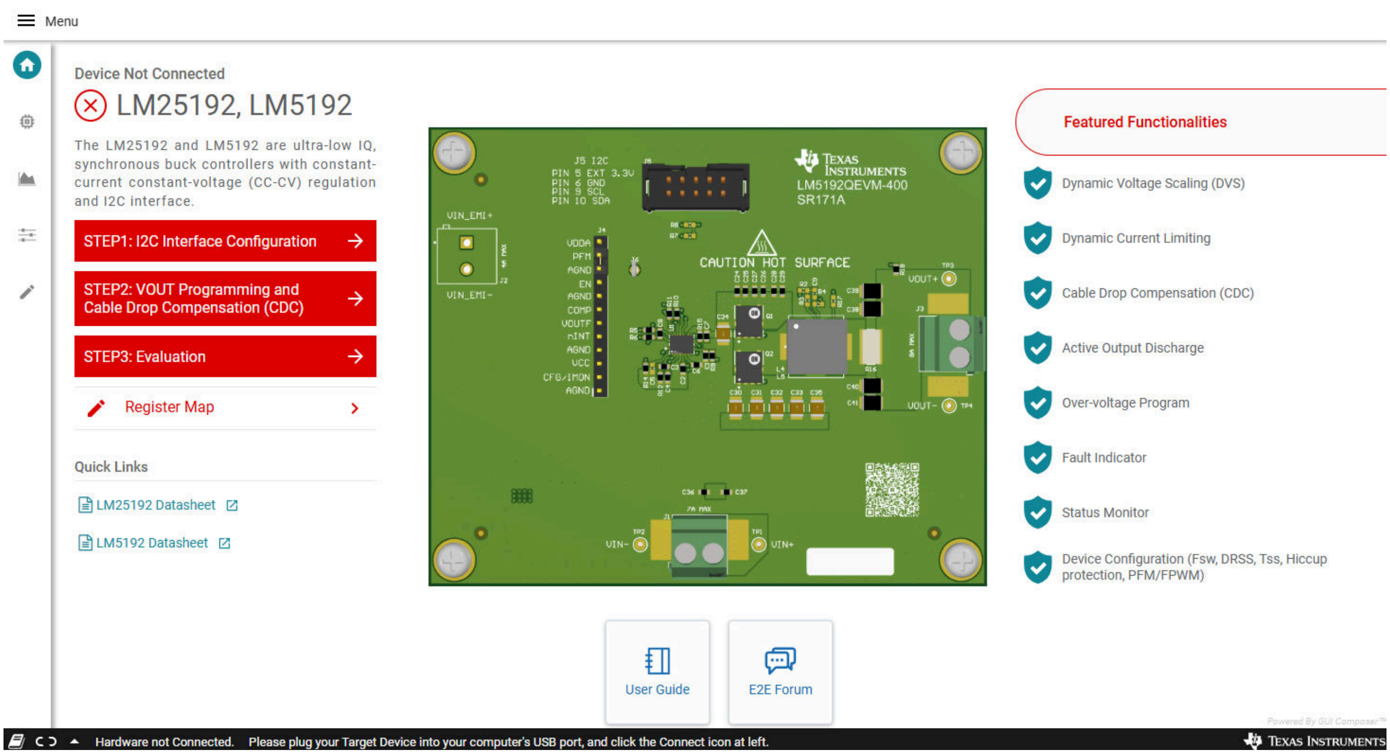


Figure 2-2. Get Started

Finish the I²C interface configuration in step 1 before programming the device. Select *LM5192* as the GPN and *5mΩ* 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 select the *CONFIGURE USB2ANY* button. Select *0x6A* as the I²C target address, and then select the *CONNECT TO EVM* button.

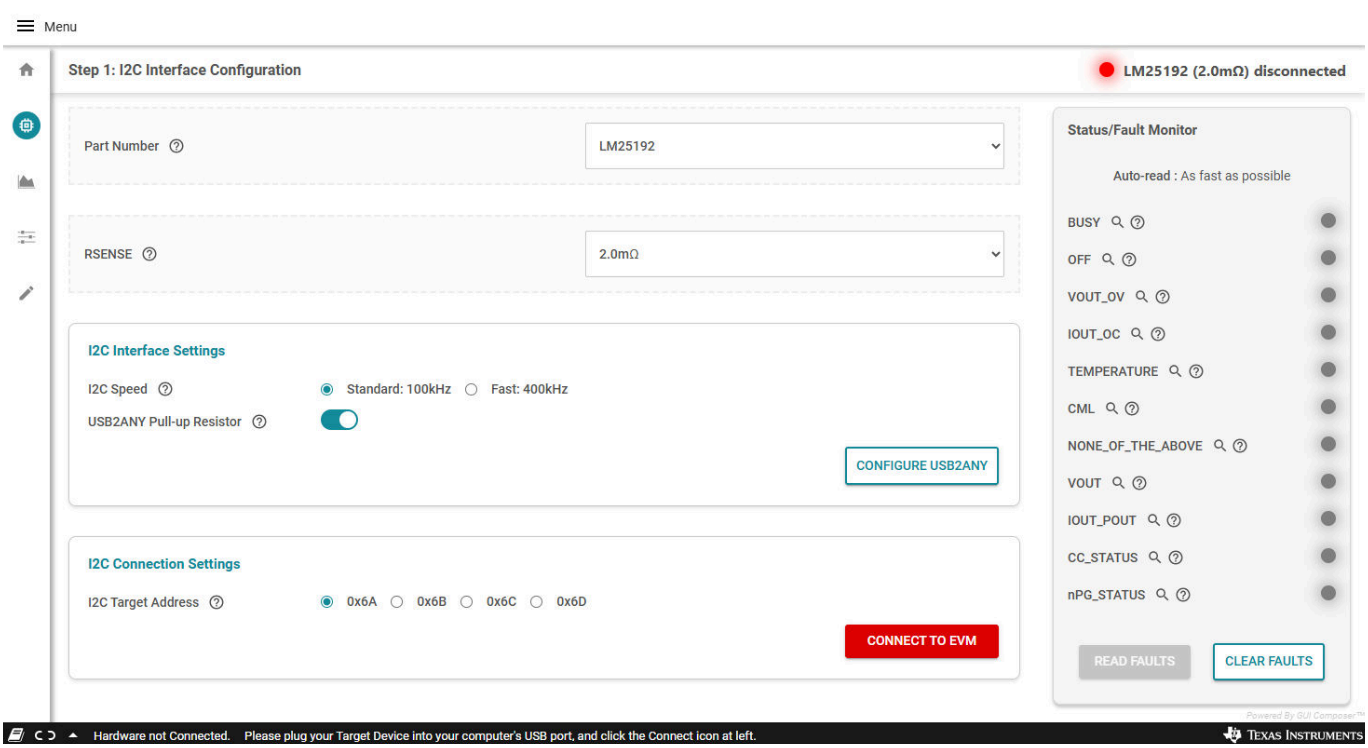


Figure 2-3. Step 1: I²C Interface Configuration

In step 2, program the VOUT regulation target to 12V as a starting point, and program the cable compensation gain if required.

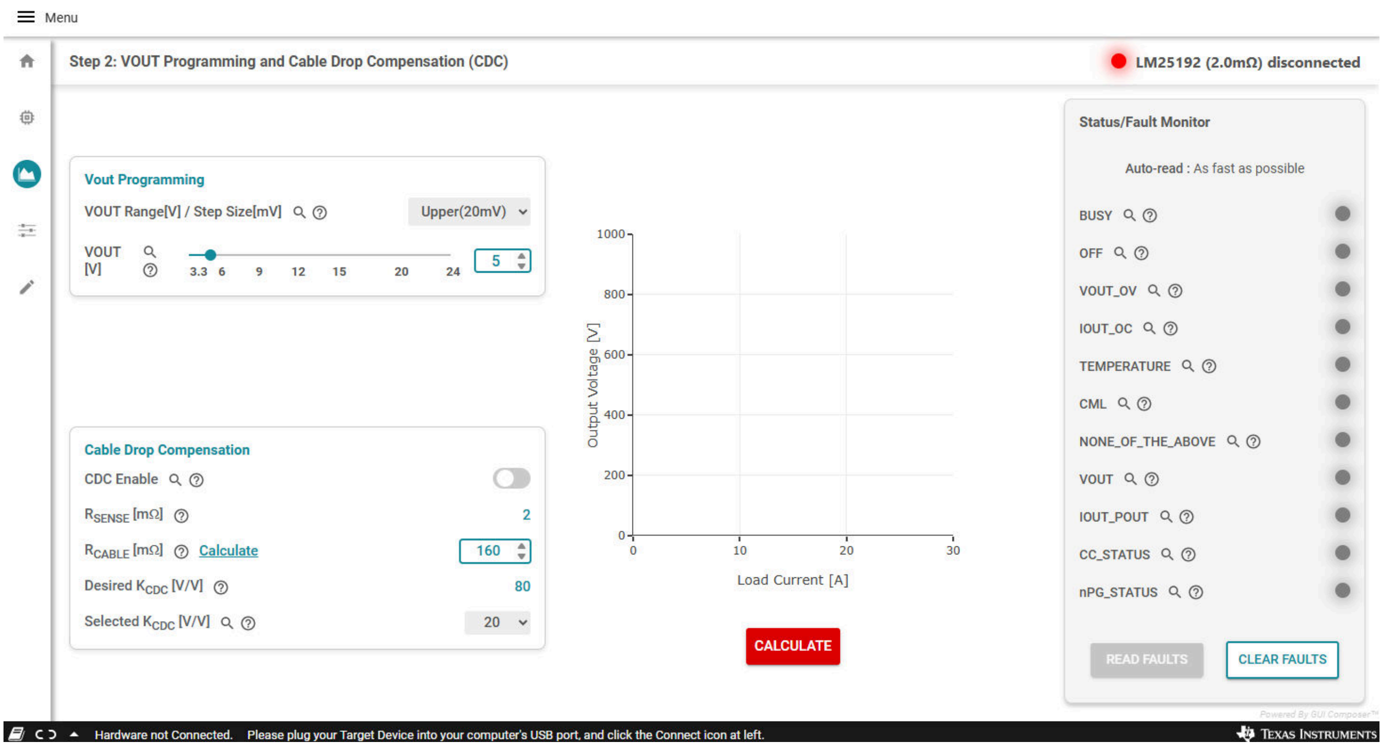


Figure 2-4. Step 2: VOUT Programming and CDC

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 8A 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.

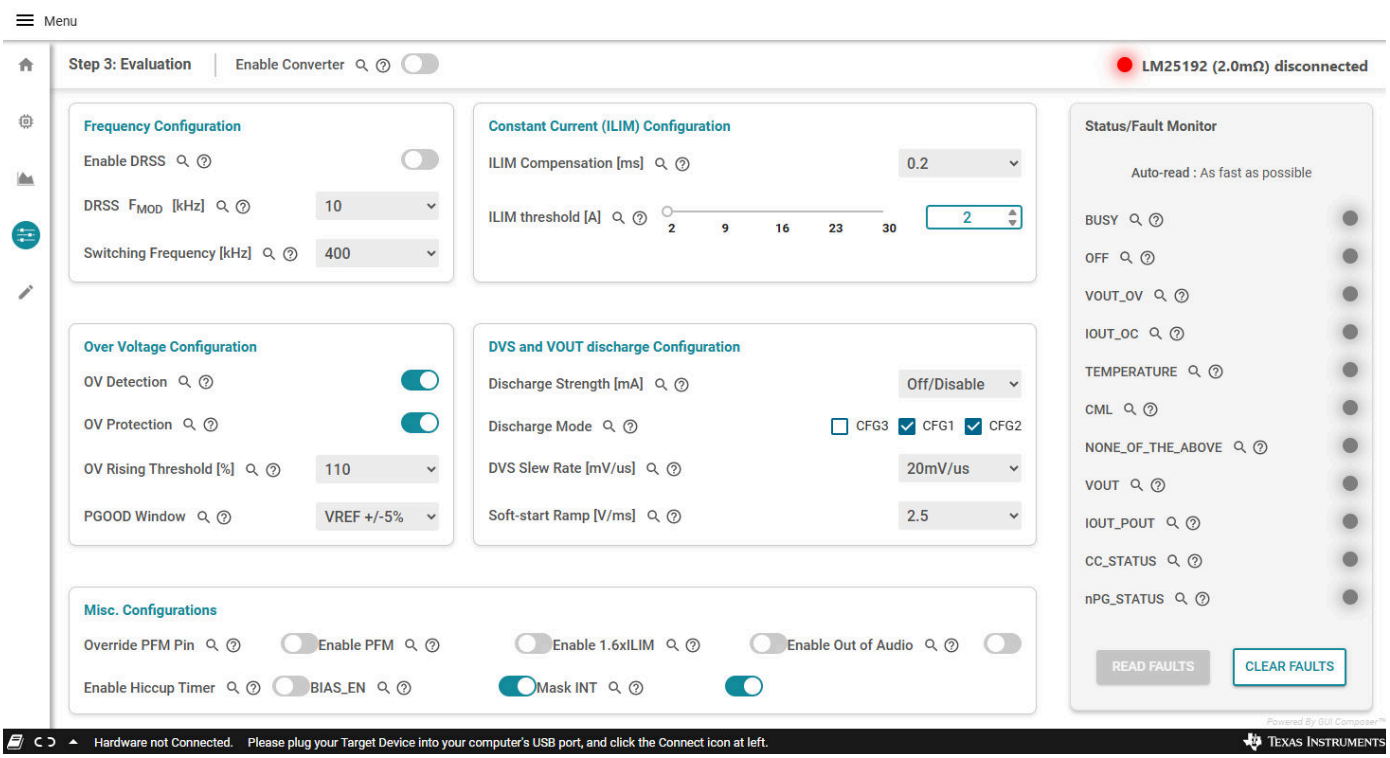


Figure 2-5. Step 3: Evaluation

Each I^{2}C registers and bits can be monitored or programed in the register map. Please program the I^{2}C register map directly if familiar with the device operation and the I^{2}C interface.

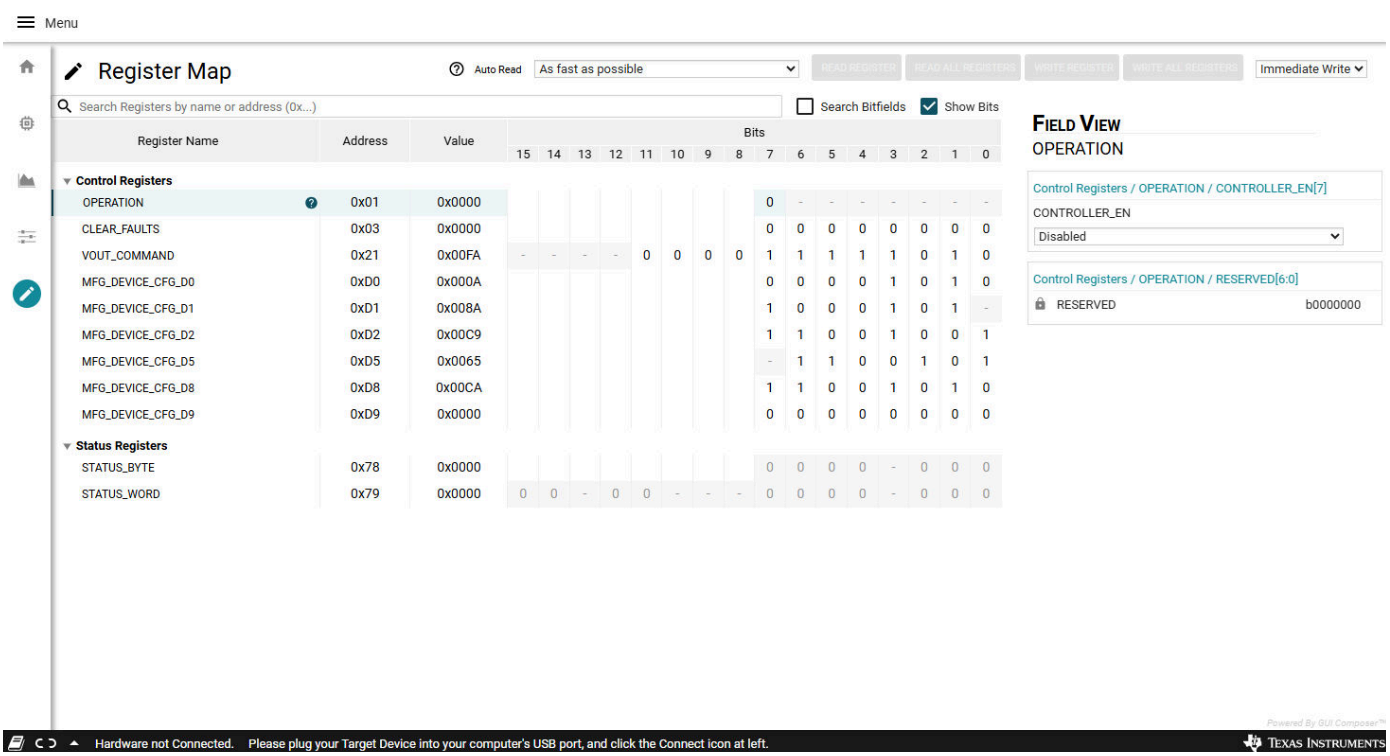


Figure 2-6. Register Map

2.1.4.2 Basic Test Procedure

1. Set up EVM, USB2ANY, power supply, electronic load, ammeter, DVM and Configuration GUI as previously described. *Do not enable the converter.*
2. Set the load to constant-voltage (CV) mode and set to 14V.
3. Set the current limit of the input supply to 0.1A maximum.
4. Set the input source 48V and turn on.
5. Program and enable the converter by I^2C. Program the output voltage to 12V, and program the ILIM threshold to 8A.
6. Set the current limit of the input supply to 10A maximum.
7. Set the load voltage to 11V. The load current must be within the 8A regulation target.
8. Set the load voltage to 14V. The load voltage must be within the 12V regulation target and the load current must be 0A.
9. Disable the converter by I^2C.
10. Turn off the input power source.

3 Implementation Results

3.1 Test Data and Performance Curves

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

3.1.1 Efficiency

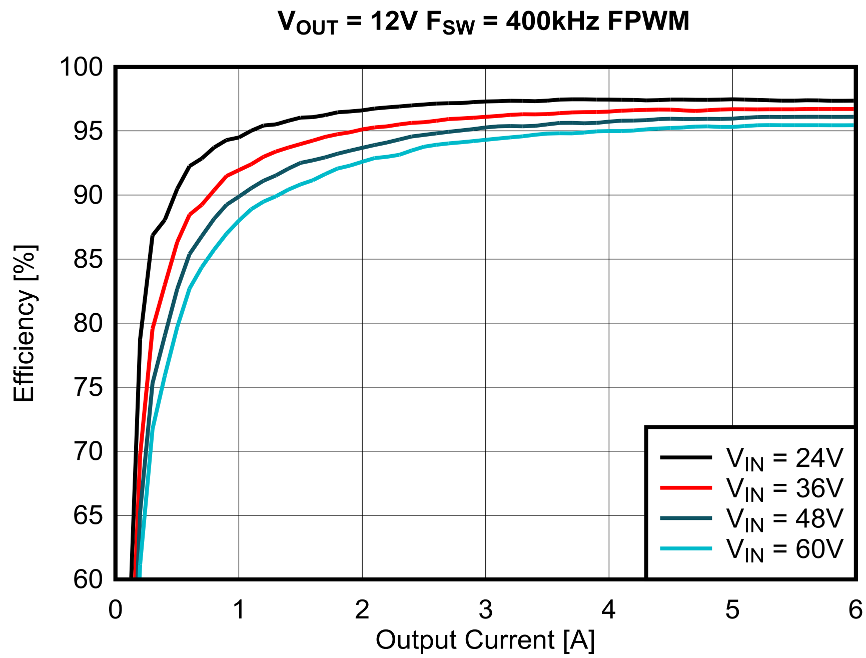


Figure 3-1. FPWM Mode, Linear Scale

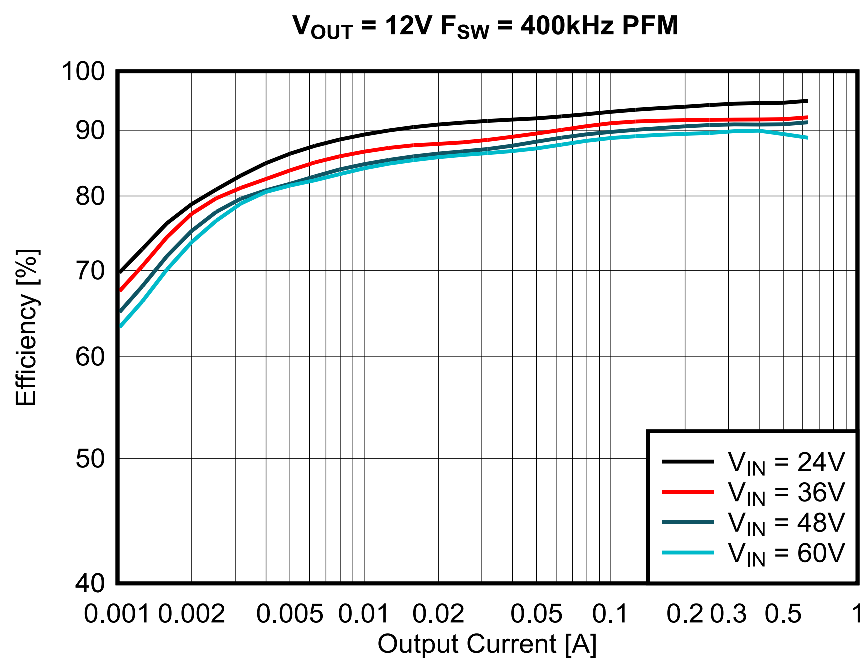


Figure 3-2. PFM Mode, Log Scale

3.1.2 Operating Waveforms

3.1.2.1 Start-Up and Shutdown

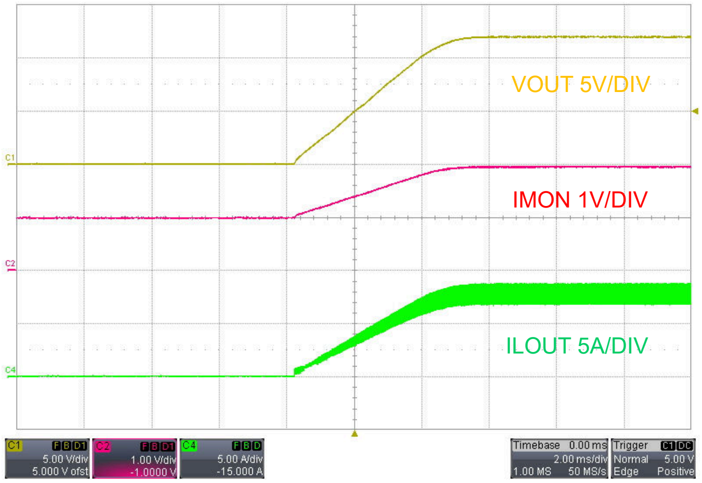


Figure 3-3. V_{SUPPLY} = 48V, I_{LOAD} = 8A Resistive Load

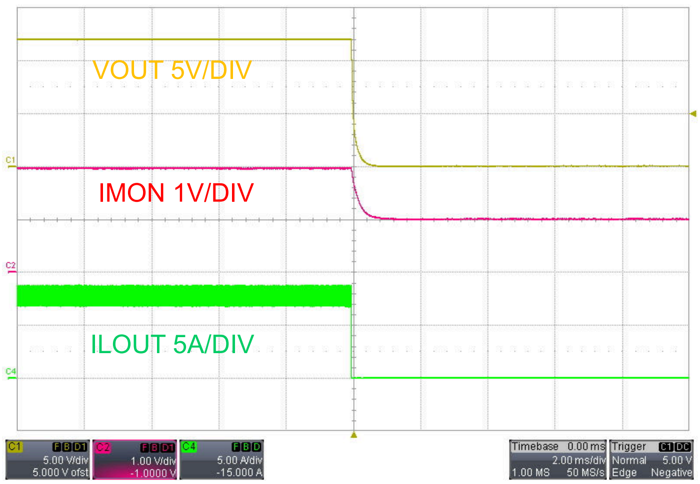


Figure 3-4. V_{SUPPLY} = 48V, I_{LOAD} = 8A Resistive Load

3.1.2.2 Switching

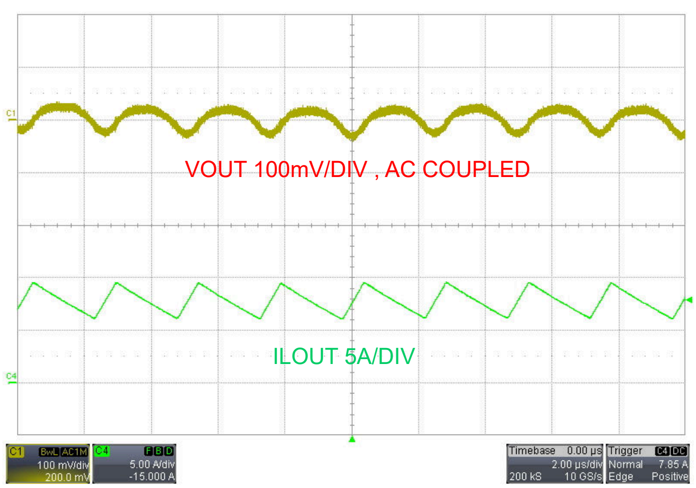


Figure 3-5. Output Ripple, V_{SUPPLY} = 48V, I_{LOAD} = 8A

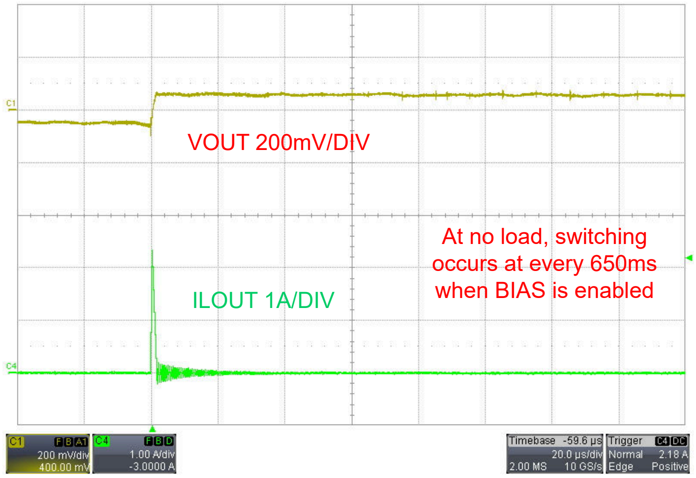


Figure 3-6. No Load Operation in PFM Mode, V_{SUPPLY} = 48V, I_{LOAD} = 0A

3.1.2.3 Load Transient (CV), Mode Transition (CV to CC)

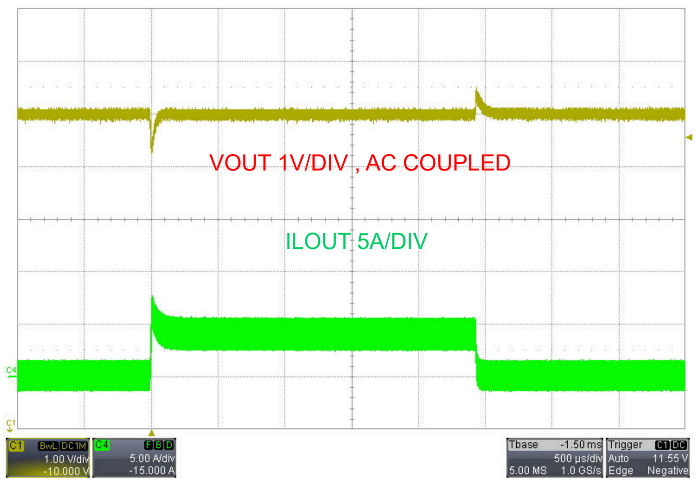


Figure 3-7. Load Transient Response, V_{SUPPLY} = 48V, FPWM, 0A to 4A

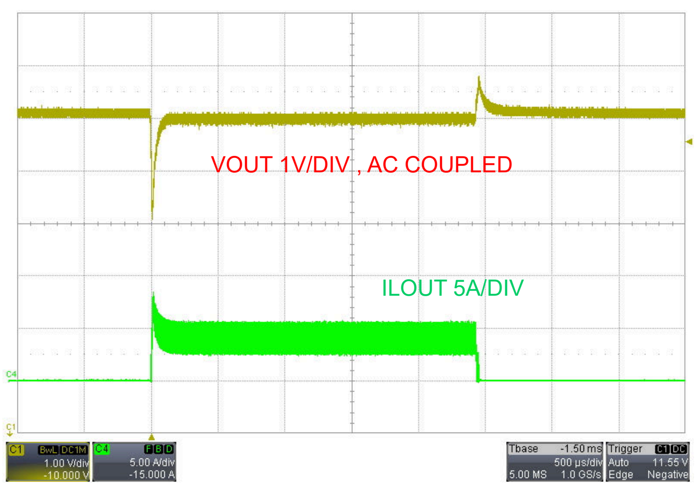


Figure 3-8. Load Transient Response, V_{SUPPLY} = 48V, PFM, 0A to 4A

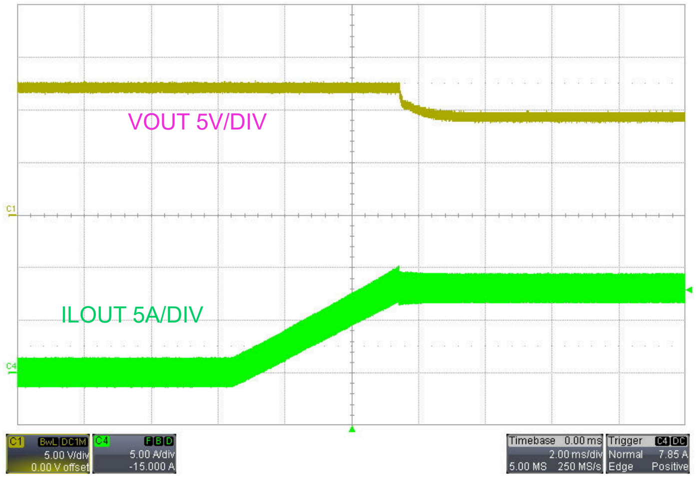


Figure 3-9. CV to CC mode Transition, V_{SUPPLY} = 48V, V_{LOAD} = 12V to 9V

3.1.3 Thermal Performance

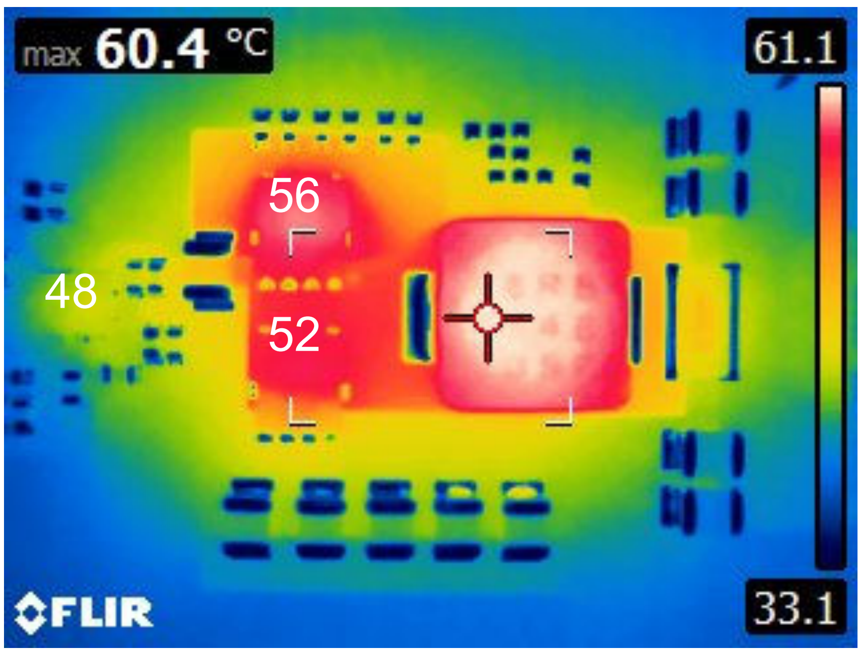


Figure 3-10. Thermal Performance, V_{SUPPLY} = 48V, V_{LOAD} = 12V, I_{LOAD} = 8A, T_A = 25°C, No Airflow

3.1.4 EMI Performance

Populated EMI filter components during EMI test (L1 : XGL4040-222MEC, L2 : CM7060P701R-10, C11 : 20uF).

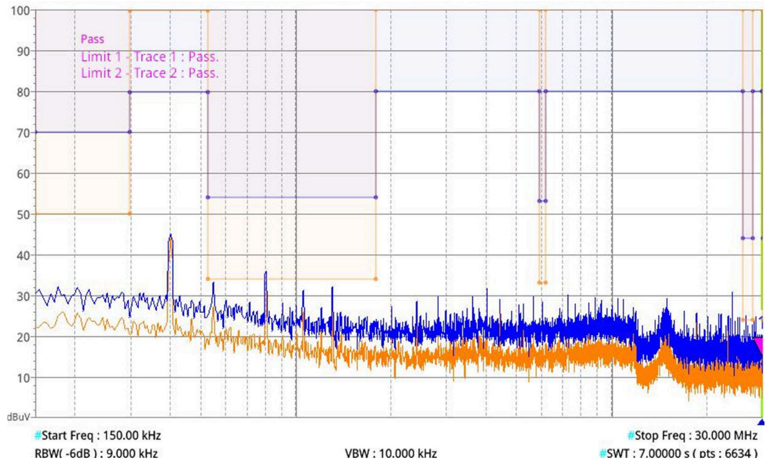


Figure 3-11. 150kHz to 30MHz, V_{SUPPLY} = 48V, V_{LOAD} = 12V, R_{LOAD} = 2Ω

4 Hardware Design Files

4.1 Schematic

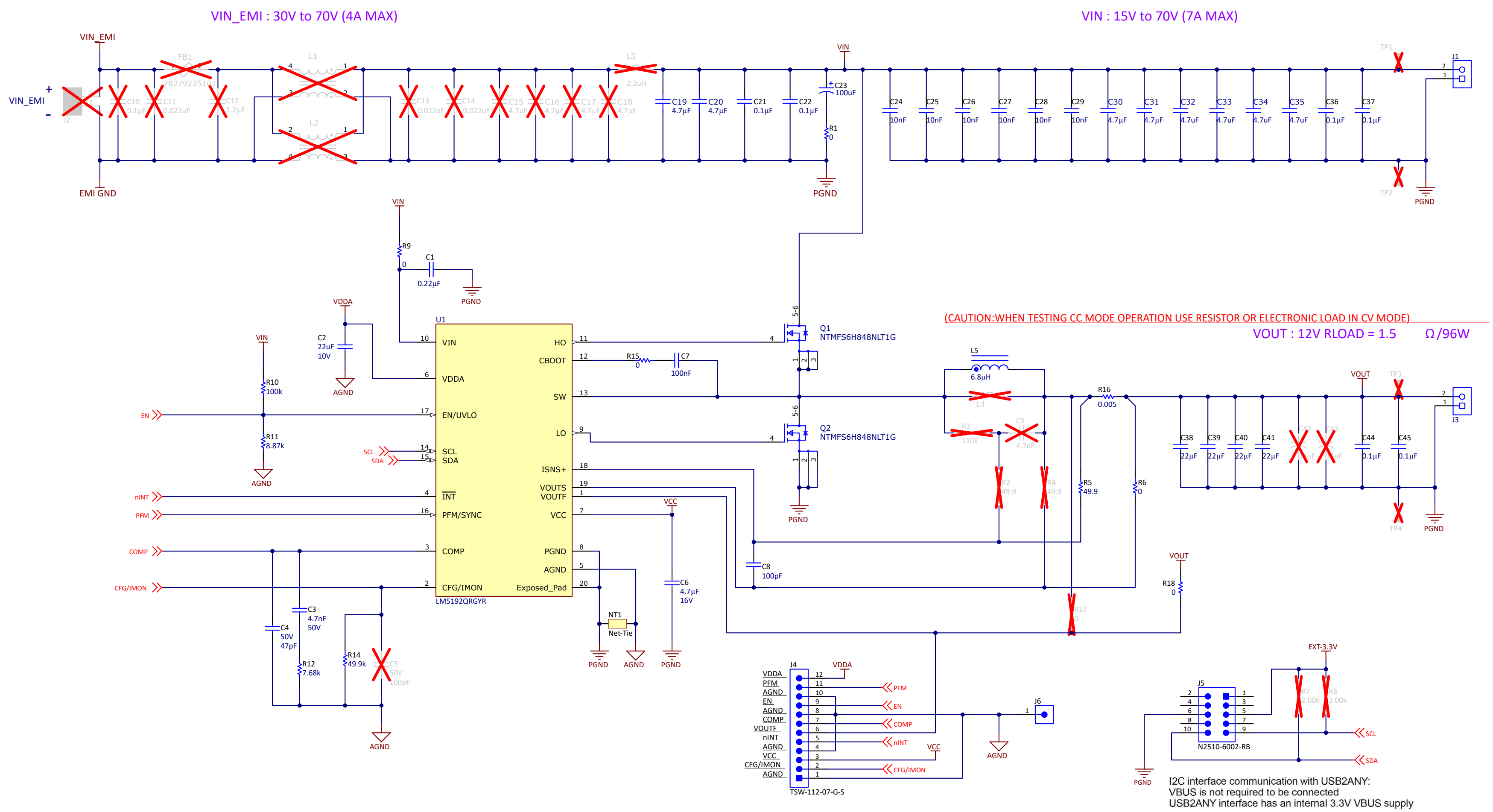


Figure 4-1. EVM Schematic

4.2 PCB Layout

LM5192QEVM-400 uses a 6-layer PCB with 2oz copper thickness.

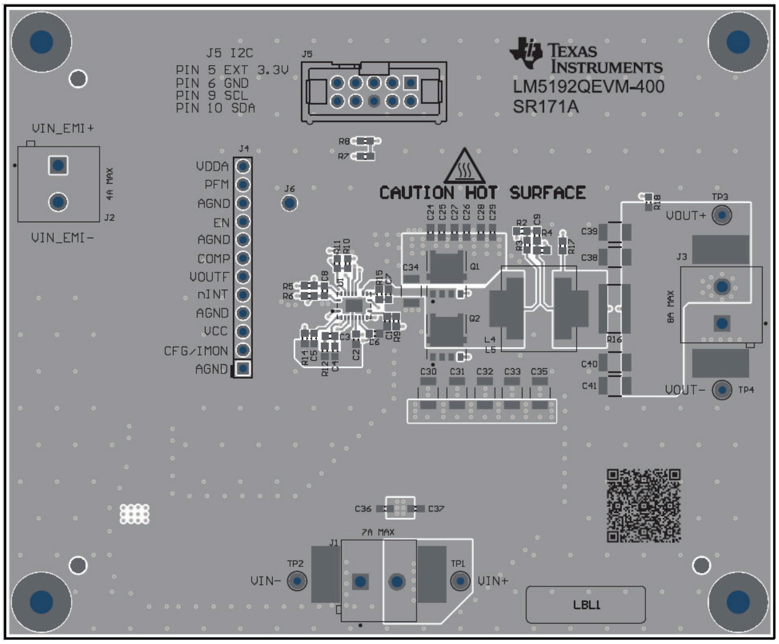


Figure 4-2. Top Components (Top View)

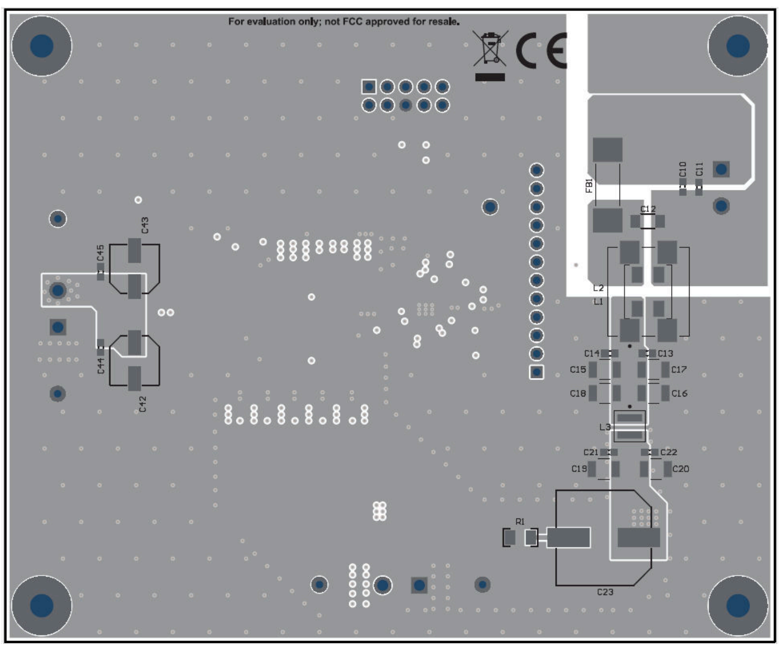


Figure 4-3. Bottom Components (Bottom View)

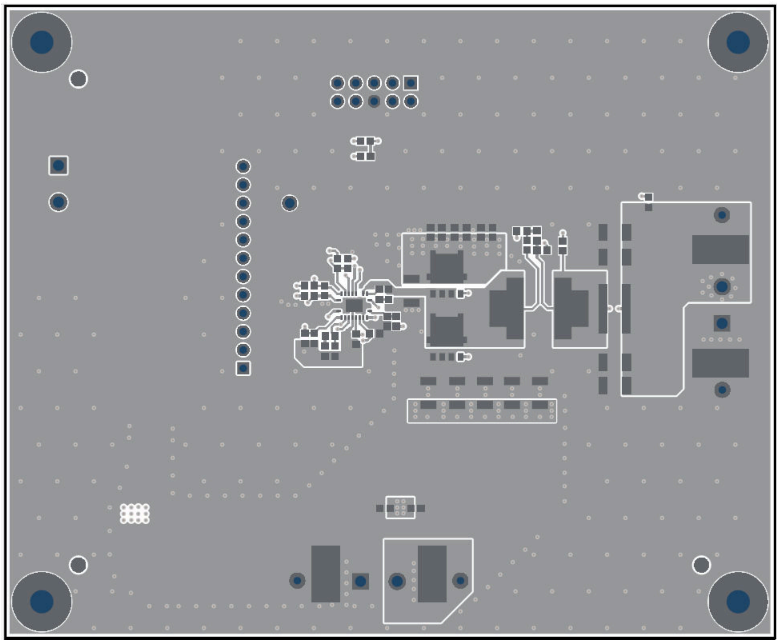


Figure 4-4. Top Layer Copper (Top View)

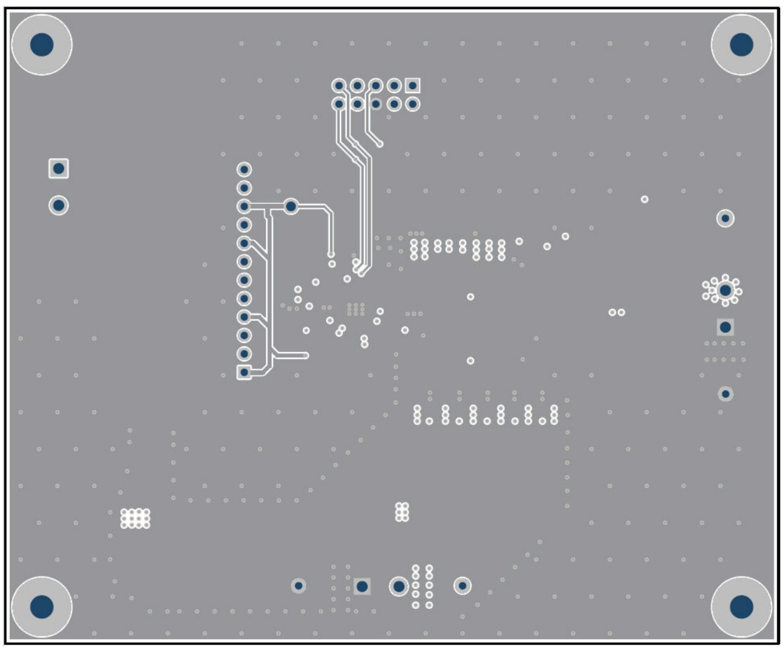


Figure 4-5. Layer 2 Copper (Top View)

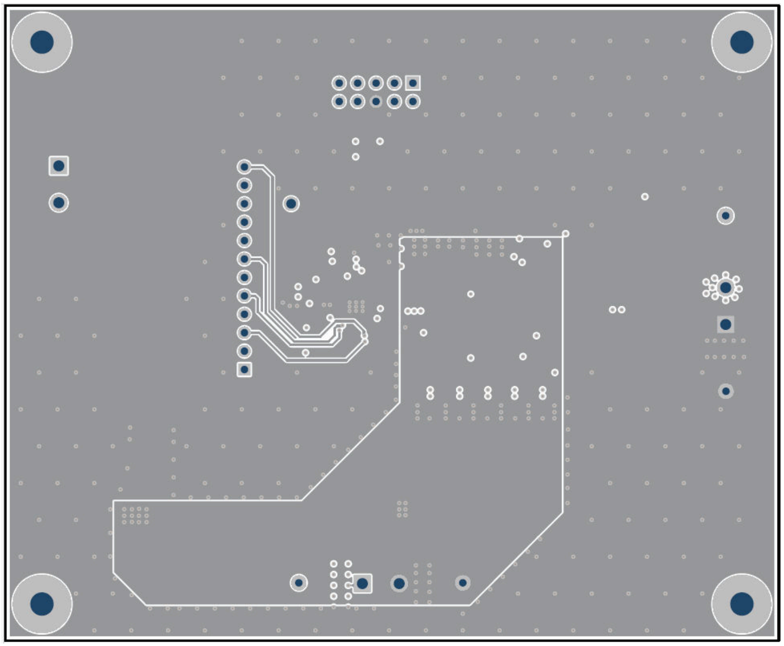


Figure 4-6. Layer 3 Copper (Top View)

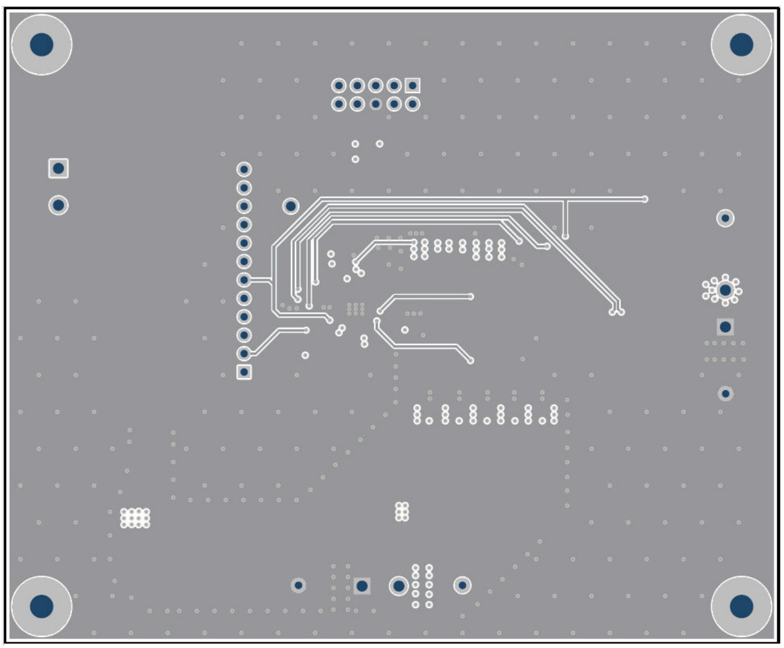


Figure 4-7. Layer 4 Copper (Top View)

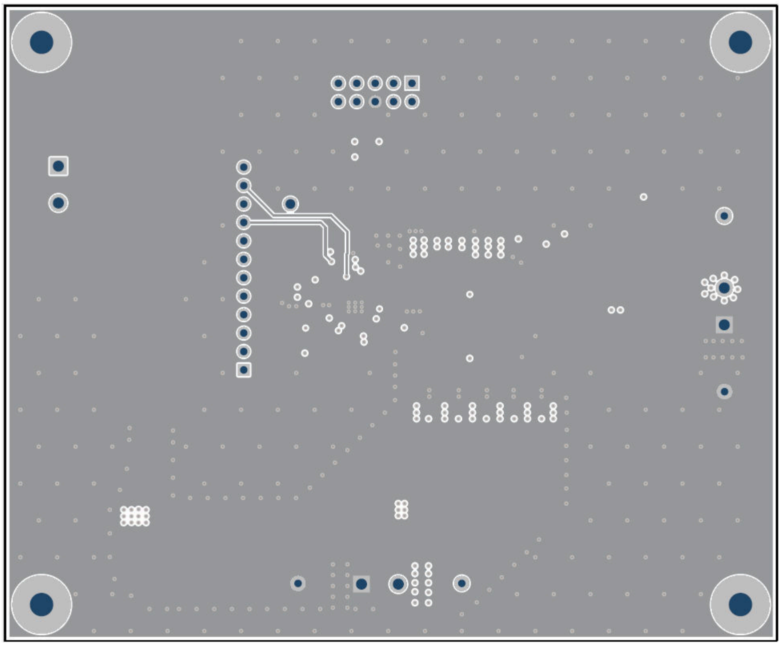


Figure 4-8. Layer 5 Copper (Top View)

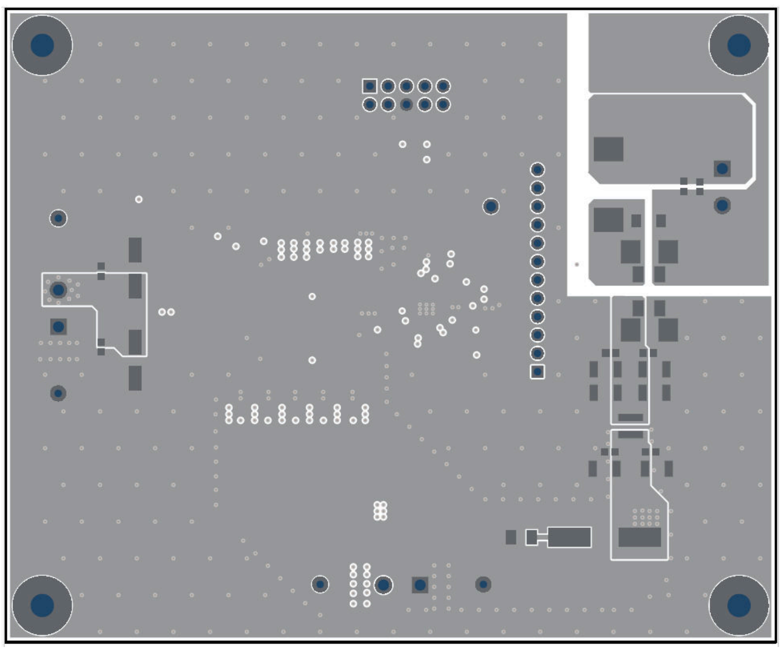


Figure 4-9. Bottom Copper (Bottom View)

4.3 Bill of Materials

Table 4-1. Bill of Materials

QTY	REF DES	DESCRIPTION	PART NUMBER	MFR
1	C1	CAP, CERM, 0.22 µF, 100V,+/- 20%, X7S, AEC-Q200 Grade 1, 0603	HMK107C7224MAHTE	Taiyo Yuden
1	C2	CAP, CERM, 22uF, 10V, +/- 20%, X5R, 0603	C1608X5R1A226M080AC	TDK
1	C3	CAP, CERM, 4700pF, 50V, +/- 5%, X7R, 0603	C0603C472J5RACTU	Kemet
1	C4	CAP, CERM, 47pF, 50V, +/- 5%, C0G/NP0, 0603	GRM1885C1H470JA01D	MuRata
1	C6	CAP, CERM, 4.7uF, 16V,+/- 10%, X7R, 0603	GRM188Z71C475KE21D	MuRata
7	C7, C21, C22, C36, C37, C44, C45	CAP, CERM, 0.1 µF, VAC/100VDC,+/- 20%, X7R, AEC-Q200 Grade 1, 0603	HMK107B7104MAHT	Taiyo Yuden
1	C8	CAP, CERM, 100pF, 100V, +/- 5%, C0G/NP0, 0603	GRM1885C2A101JA01D	MuRata
8	C19, C20, C30, C31, C32, C33, C34, C35	4.7 µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric)	CNC6P1X7R2A475K250AE	TDK
1	C23	CAP, AL, 100uF, 100V, +/- 20%, 0.33ohm, SMD	EMVY101ATR101MKE0S	Chemi-Con
6	C24, C25, C26, C27, C28, C29	CAP, CERM, 0.01 µF, 100V,+/- 10%, X7R, 0603	885012206114	Wurth Elektronik
4	C38, C39, C40, C41	CAP, CERM, 22 µF, 25V,+/- 10%, X7R, 1210	C1210C226K3RAC7800	Kemet
4	H1, H2, H3, H4	Machine Screw, Round, #4-40x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
4	H5, H6, H7, H8	Standoff, Hex, 1"L #4-40 Nylon	1902E	Keystone
2	J1, J3	5.08mm terminal block, Horizontal	691253510002	Wurth Electronics
1	J4	Header, 100mil, 12x1, Gold, TH	TSW-112-07G-S	Samtec
1	J5	Header (shrouded), 100mil, 5x2, High-Temperature, Gold, TH	N2510-6002-RB	3M
1	J6	Test Point Slotted	1040	Keystone
1	L5	Inductor, Drum Core, Powdered Iron, 6.8 µH, 10.8A, 0.014ohm, AEC-Q200 Grade 0, SMD	VCHA105D-6R8MS6	Cyntec
1	LBL1	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	THT-14-423-10	Brady
2	Q1, Q2	N-Channel 80V 13A (Ta), 59A (Tc) 3.7W (Ta), 73W (Tc) Surface Mount 5-DFN (5x6) (8-SOFL)	NTMFS6H848NLT1G	onsemi
1	R1	RES, 0, 5%, 0.25W, AEC-Q200 Grade 0, 1206	RCA12060000ZSEA	Vishay-Dale
1	R5	RES, 49.9, 1%, 0.1W, AEC-Q200 Grade 0, 0603	ERJ-3EKF49R9V	Panasonic
4	R6, R9, R15, R18	RES, 0, 5%, 0.1W, 0603	RC0603JR-070RL	Yageo
1	R10	RES, 100k, 1%, 0.1W, 0603	RC0603FR-07100KL	Yageo
1	R11	RES, 8.87k, 1%, 0.1W, AEC-Q200 Grade 0, 0603	CRCW06038K87FKEA	Vishay-Dale
1	R12	RES, 7.68k, 1%, 0.1W, AEC-Q200 Grade 0, 0603	CRCW06037K68FKEA	Vishay-Dale
1	R14	RES, 49.9k, 1%, 0.1W, 0603	RC0603FR-0749K9L	Yageo
1	R16	RES, 0.005, 1%, 2W, 2512 WIDE	FCSL64R005FER	Ohmite
1	SH-J4	Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
1	U1	80V, Automotive, High-Efficiency CC-CV Buck Controller with I2C	LM5192QRGYR	Texas Instruments

5 Additional Information

5.1 Trademarks

PowerPAD™ is a trademark of Texas Instruments.
WEBENCH® and SIMPLE SWITCHER® are registered trademarks of Texas Instruments.
All trademarks are the property of their respective owners.

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

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.