EVM User's Guide: LM5190QEVM-400

LM5190-Q1 CCCV Buck Controller Evaluation Module

TEXAS INSTRUMENTS

Description

The LM5190QEVM-400 evaluation module (EVM) is a synchronous buck DC/DC regulator with constant-current constant-voltage (CCCV) regulation. The EVM operates over a wide input voltage range of 15V to 72V (at J1 VIN terminal), providing a regulated current of 8A in CC mode and a regulated voltage of 12V in CV mode. The regulation target of the average inductor current is programmed by ISET and the output voltage is adjusted by modifying the feedback resistors.

Features

- Wide input voltage operating range
  - 15V to 72V: VIN terminal
- Fixed 12V, 5V, or adjustable output voltage
- Adjustable average inductor current using ISET
- Inductor current monitor using IMON
- Integrated standard MOSFET gate drivers
- 18µA standby current at V_{SUPPLY} = 48V with BIAS

- Full-load efficiency of 95% at V_{SUPPLY} = 48V
- 400kHz switching frequency with optional external clock synchronization
- Dual-random spread spectrum
- Integrated slope compensation
- Forced PWM (FPWM) or pulsed-frequency modulation (PFM) operation
- Over-current protection (OCP) with hiccup mode for abnormal overload conditions
- Power Good indicator with pullup resistor to VCC
- Internal 2.75ms soft start in CV mode
- CC mode soft start using C_{ISET} capacitor
- Thermally efficient layout with 6-layer 2-oz PCB

Applications

- Super capacitor energy backup
- E-bikes
- Power tools
- Server battery-backup unit (BBU)
- Energy storage system and solar energy
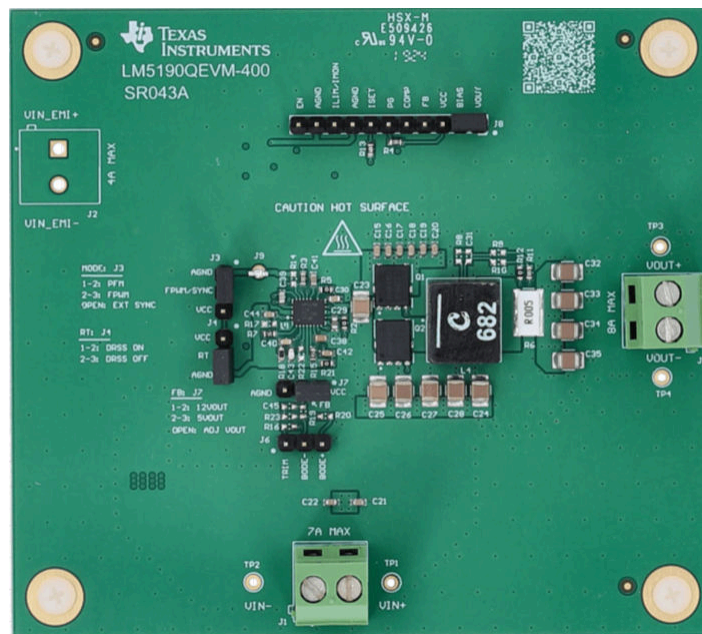
LM5190Q1EVM

1 Evaluation Module Overview

1.1 Introduction

The LM5190QEVM-400 EVM is a synchronous buck DC/DC regulator with constant-current constant-voltage (CCCV) regulation. The EVM operates over a wide input voltage range of 15V to 72V (VIN terminal), providing a regulated current of 8A in CC mode and a regulated voltage of 12V in CV mode. The average inductor current is programmed by controlling the ISET pin voltage and the output voltage is adjusted by modifying the feedback resistor values.

The EVM features internal (for the fixed 5V, 12V) or external feedback, selectable DRSS, FPWM/PFM selection jumper and injection point for CV mode loop response measurement. The free-running switching frequency is 400kHz and is synchronizable to an external clock signal at a higher or lower frequency. External feedback resistors and 50Ω injection resistor can be populated to measure the loop response in CV mode.

1.2 Kit Contents

- One LM5190QEVM-400 EVM board
- EVM disclaimer Read Me

1.3 Specification

Table 1-1 table lists the electrical characteristics of the evaluation module. See the LM5190-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	72	V
Input current, I_{SUPPLY}					7	A
Input current, no load	PFM, BIAS=VOUT, EN =VIN, internal feedback	V_{SUPPLY} = 24V		22		μA
		V_{SUPPLY} = 48V		18		
		V_{SUPPLY} = 72V		17		
OUTPUT CHARACTERISTICS						
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		96.8%		
		V_{SUPPLY} = 48V		95.0%		
		V_{SUPPLY} = 60V		94.3%		

1.4 Device Information

Table 1-2. LM(2)5190(-Q1) Synchronous Buck Controller Family with Integrated CCCV control

DC/DC Controller	Input Range	Output Range	f_{SW} range (RT)	Gate Driver	Automotive Qualification
LM25190	5V to 42V	0.8V to 42V	100kHz to 2.2MHz	Standard	-
LM5190	5V to 80V	0.8V to 80V	100kHz to 2.2MHz	Standard	-
LM25190-Q1	5V to 42V	0.8V to 42V	100kHz to 2.2MHz	Standard	AEC-Q100 Grdae1
LM5190-Q1	5V to 80V	0.8V to 80V	100kHz to 2.2MHz	Standard	AEC-Q100 Grade1

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.
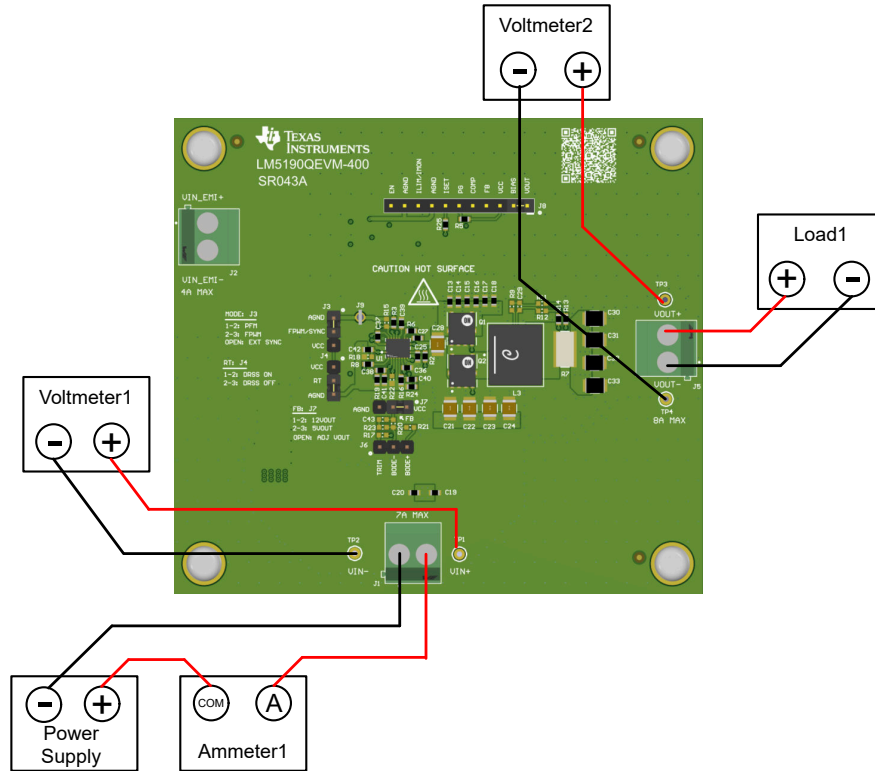
Figure 2-1. EVM Test Setup

CAUTION

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

Table 2-1. Power Connections

REF DES	LABEL	DESCRIPTION
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.
J5	VOUT+	Positive output voltage power connection.
J5	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. J8 Jumper

NUMBER	LABEL	DESCRIPTION
1	VOUT	VOUT connection.
2	BIAS	BIAS connection. Connect #1 to #2 for the external BIAS supply from VOUT.
3	VCC	VCC connection.
4	FB	FB connection.
5	COMP	COMP connection
6	PG	PGOOD connection. An open-collector output is connected to VCC through 100kΩ pull-up resistor.
7	ISET	ISET connection. Dynamic current setting pin for the constant current operation.
8	AGND	Ground connection.
9	ILIM/IMON	IMON connection. Current monitor and current limit programming pin.
10	AGND	Ground connection.
11	EN	ENABLE input. Connect #10 to #11 to disable the device.

Table 2-4. J3 Jumper

NUMBER	LABEL	DESCRIPTION
1	AGND	Ground connection.
2	FPWM/SYNC	FPWM/SYNC connection. Connect #1 to #2 for PFM . Connect #2 to #3 for FPWM. Apply external clock synchronization pulse if required.
3	VCC	VCC connection.

Table 2-5. J4 Jumper

NUMBER	LABEL	DESCRIPTION
1	VCC	VCC connection.
2	RT	Connection to RT resistor. Connect #1 to #2 during initial start-up for DRSS. Connect #2 to #3 during initial start-up for the fixed switching frequency operation.
3	AGND	Ground connection.

Table 2-6. J7 Jumper

NUMBER	LABEL	DESCRIPTION
1	VCC	VCC connection.
2	FB	FB connection. Connect #1 to #2 for the 12V fixed output using internal feedback. Connect #2 to #3 for the 5V fixed output using internal feedback.
3	AGND	Ground connection.

Table 2-7. J6 Jumper

NUMBER	LABEL	DESCRIPTION
1	TRIM	Apply an external voltage to change the output regulation target dynamically.
2	BODE-	50Ω injection point for CV loop response measurement. Connected to feedback resistor.
3	BODE+	50Ω injection point for CV loop response measurement. Connected to output capacitor.

2.1.2 Test Equipment

- **Power Supply:** Use an input voltage source capable of supplying 0V to 72V 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) 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 J3, J4, J7 and J8 jumpers are 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 J5. Set the load to CV mode at 15V before applying input voltage.
2. Connect voltmeter 2 at VOUT+ and VOUT- test points to measure the output voltage.

2.1.4 Test Procedure

2.1.4.1 Basic Test Procedure

1. Set up the EVM as previously described.
2. Set the load to constant-voltage (CV) mode and set to 15V.
3. Set the input source 48V and turn on. The load voltage must be within the 12V regulation target.
4. Set the current limit of the input supply to 10A maximum.
5. Set the load voltage to 10V. The load current must be within the 8A regulation target.
6. Set the load voltage to 5V. The load current must be within the 8A regulation target.
7. Set the load voltage to 15V. The load current must be 0A.
8. **If additional output capacitors or super capacitors are connected to the output, then the additional output capacitors or the super capacitors must be fully discharged before turning off the input power source.**
9. Turn off the input power source.

3 Implementation Results

3.1 Test Data and Performance Curves

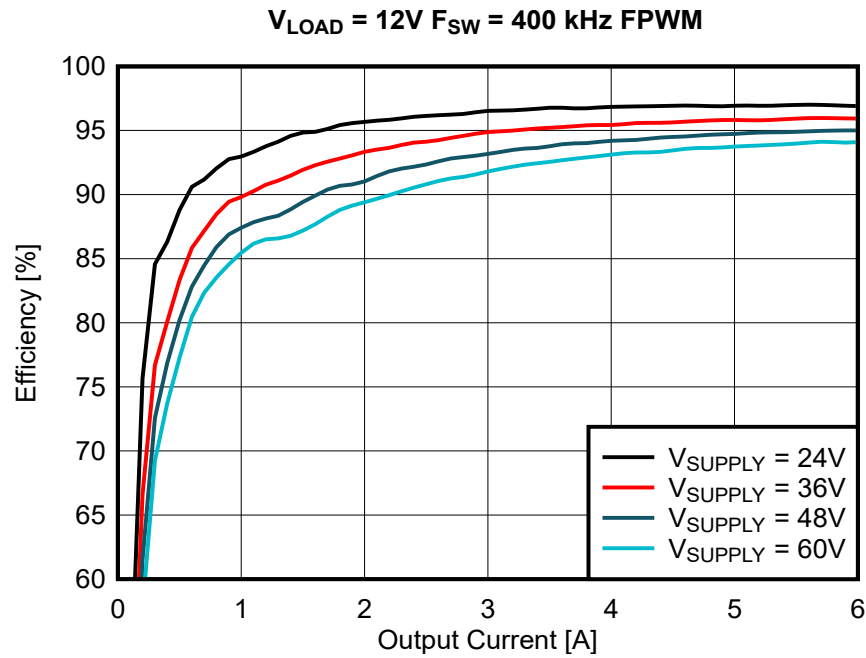Unless otherwise indicated, V_{SUPPLY} = 48V and f_{SW} = 400kHz

3.1.1 Efficiency

V_{LOAD} = 12V F_{SW} = 400 kHz FPWM

Figure 3-1. FPWM Mode, Linear Scale
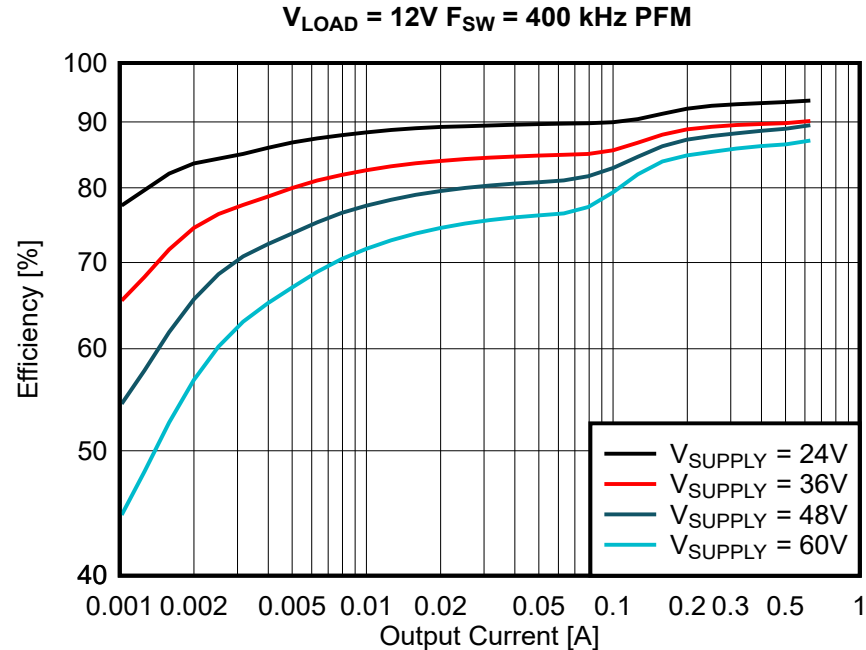
V_{LOAD} = 12V F_{SW} = 400 kHz PFM

Figure 3-2. PFM Mode, Log Scale

3.1.2 Operating Waveforms

3.1.2.1 Start-Up and Shutdown With EN
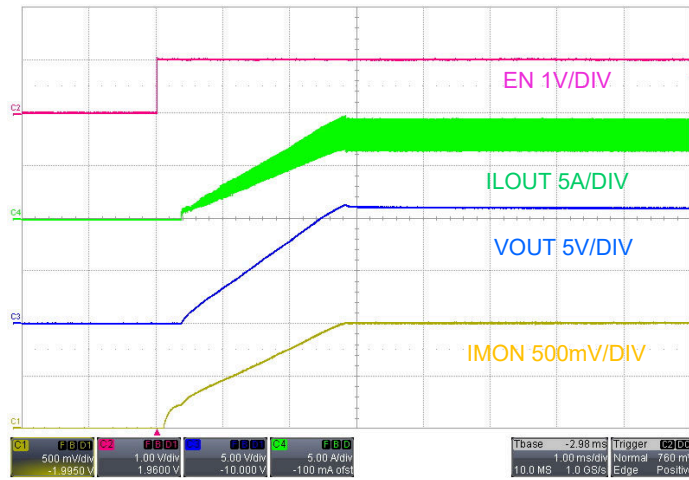
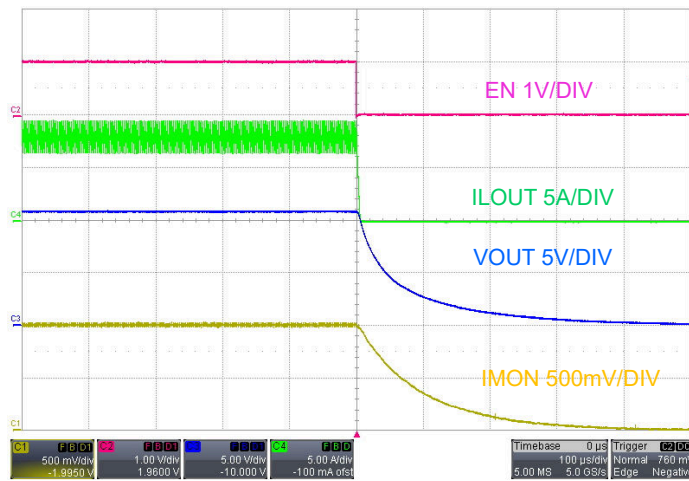**Figure 3-3. EN ON, V_{SUPPLY} = 48V, I_{LOAD} = 8A Resistive Load**

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

3.1.2.2 Switching
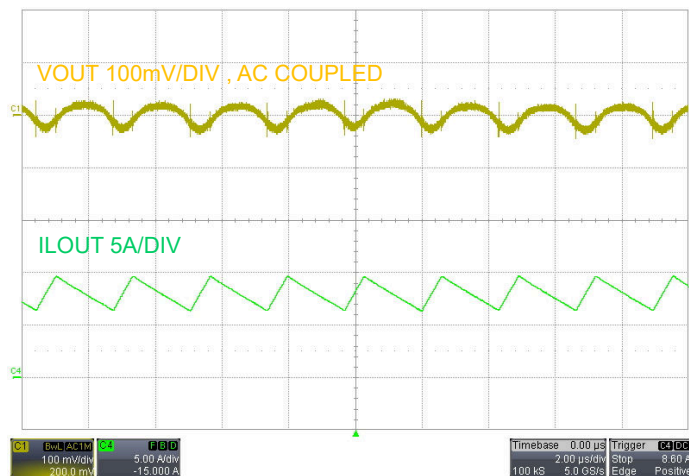
Figure 3-5. Output Ripple, V_{SUPPLY} = 48V, I_{LOAD} = 8A
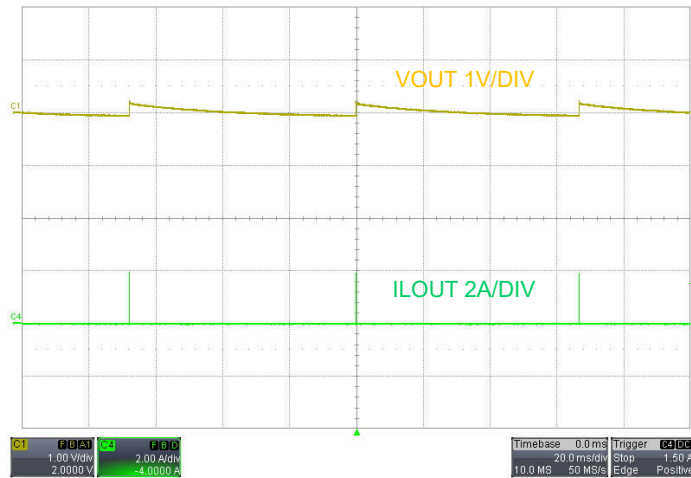
Figure 3-6. No load operation in PFM Mode, V_{SUPPLY} = 48V, I_{LOAD} = 0A

3.1.2.3 Load Transient (CV), ISET Modulation (CC)
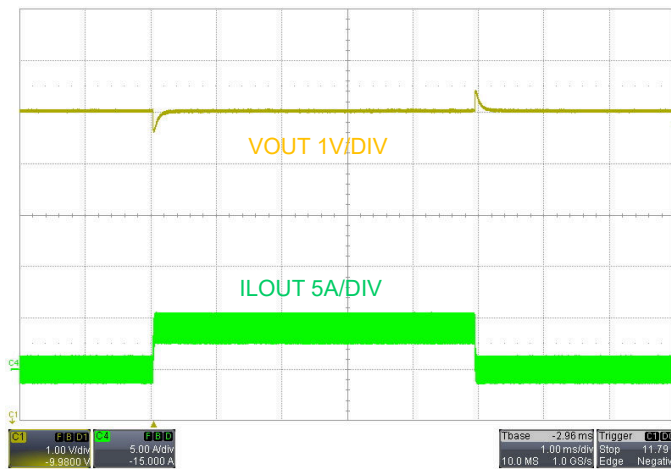
Figure 3-7. Load Transient Response, V_{SUPPLY} = 48V, FPWM, 0A to 4A
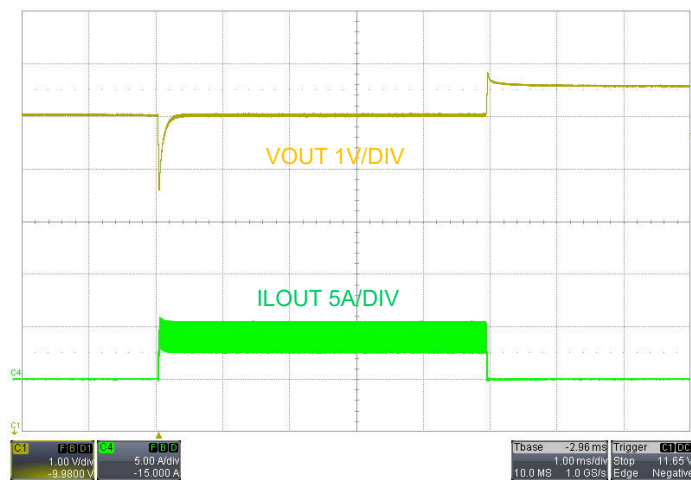
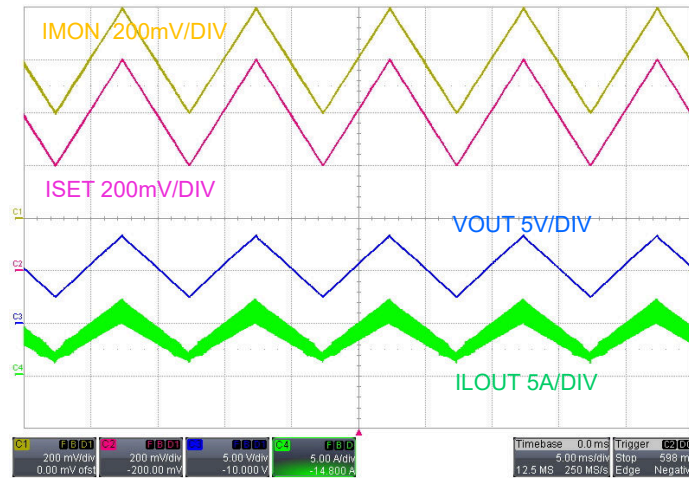**Figure 3-8. Load Transient Response, V_{SUPPLY} = 48V, PFM, 0A to 4A**

Figure 3-9. ISET Modulation, V$_{SUPPLY}$ = 48V, R$_{LOAD}$ = 1.35Ω

3.1.3 Thermal Performance
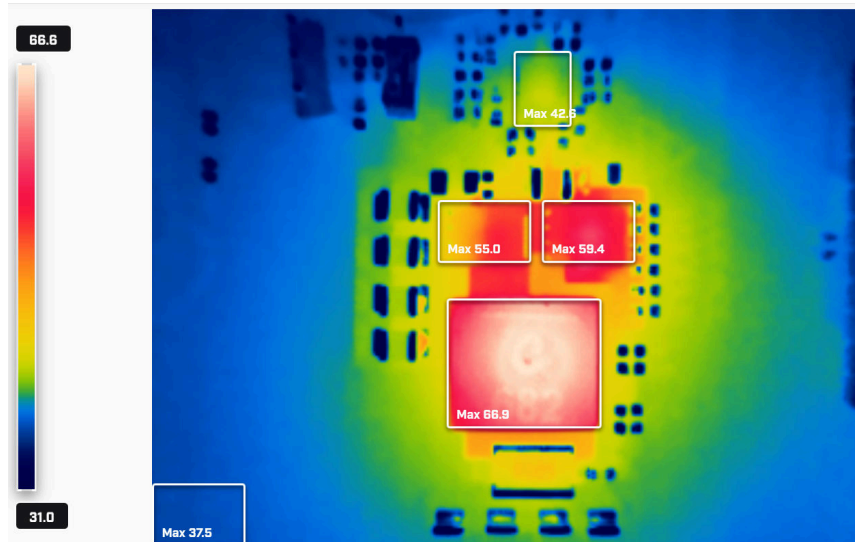
Figure 3-10. Thermal Performance, V$_{SUPPLY}$ = 48V, I$_{LOAD}$ = 8A, T$_A$ = 25°C, No Airflow

3.1.4 Bode Plot
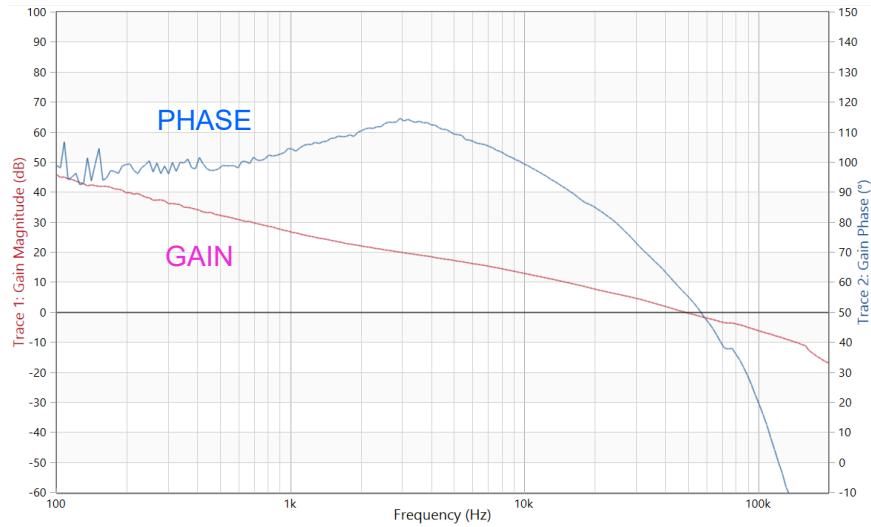
Figure 3-11. Bode Plot, V$_{SUPPLY}$ = 48V, V$_{LOAD}$ = 12V, I$_{LOAD}$ = 8A

3.1.5 EMI Performance

Populated EMI filter components during EMI test (L2 : MCM-7060M-701-RU).

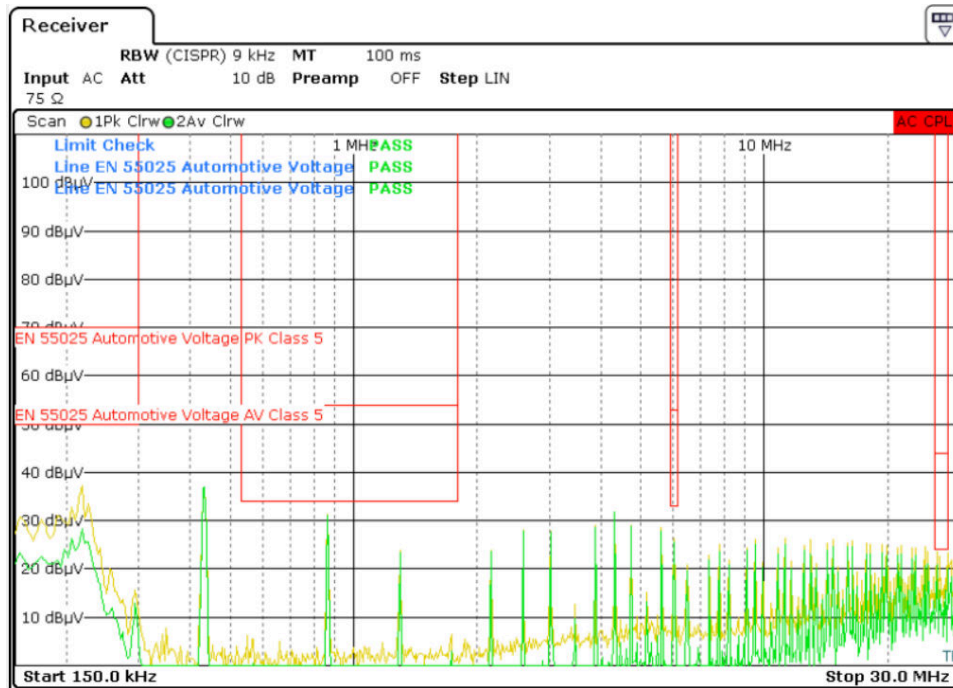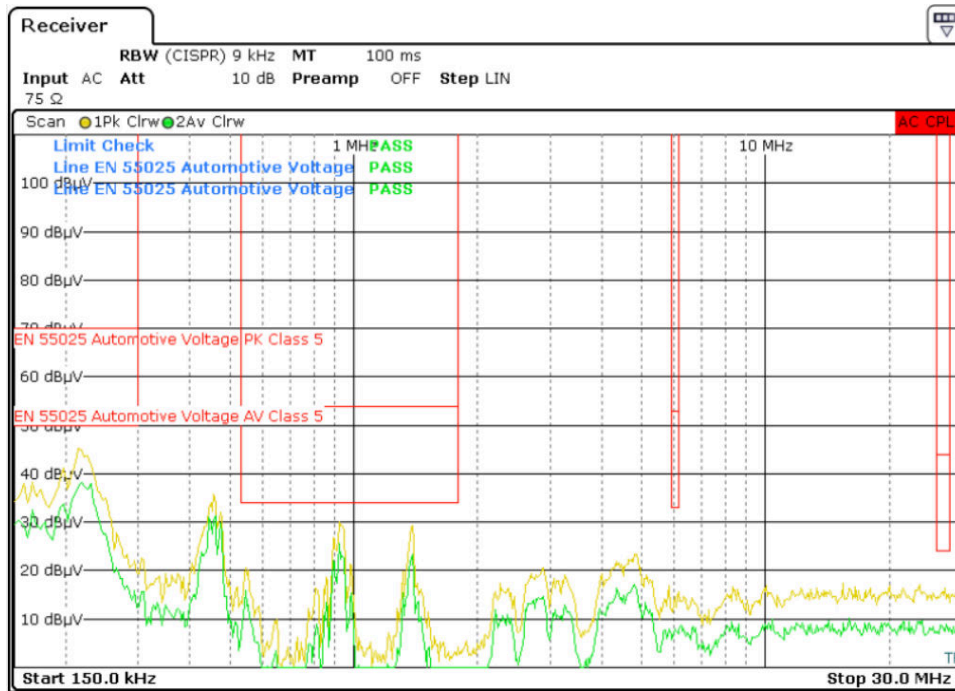**Figure 3-12. 150kHz to 30MHz, V$_{SUPPLY}$ = 48V, R$_{LOAD}$ = 1.5Ω, DRSS OFF**

Figure 3-13. 150kHz to 30MHz, V_{SUPPLY} = 48V, R_{LOAD} = 1.5Ω, DRSS ON

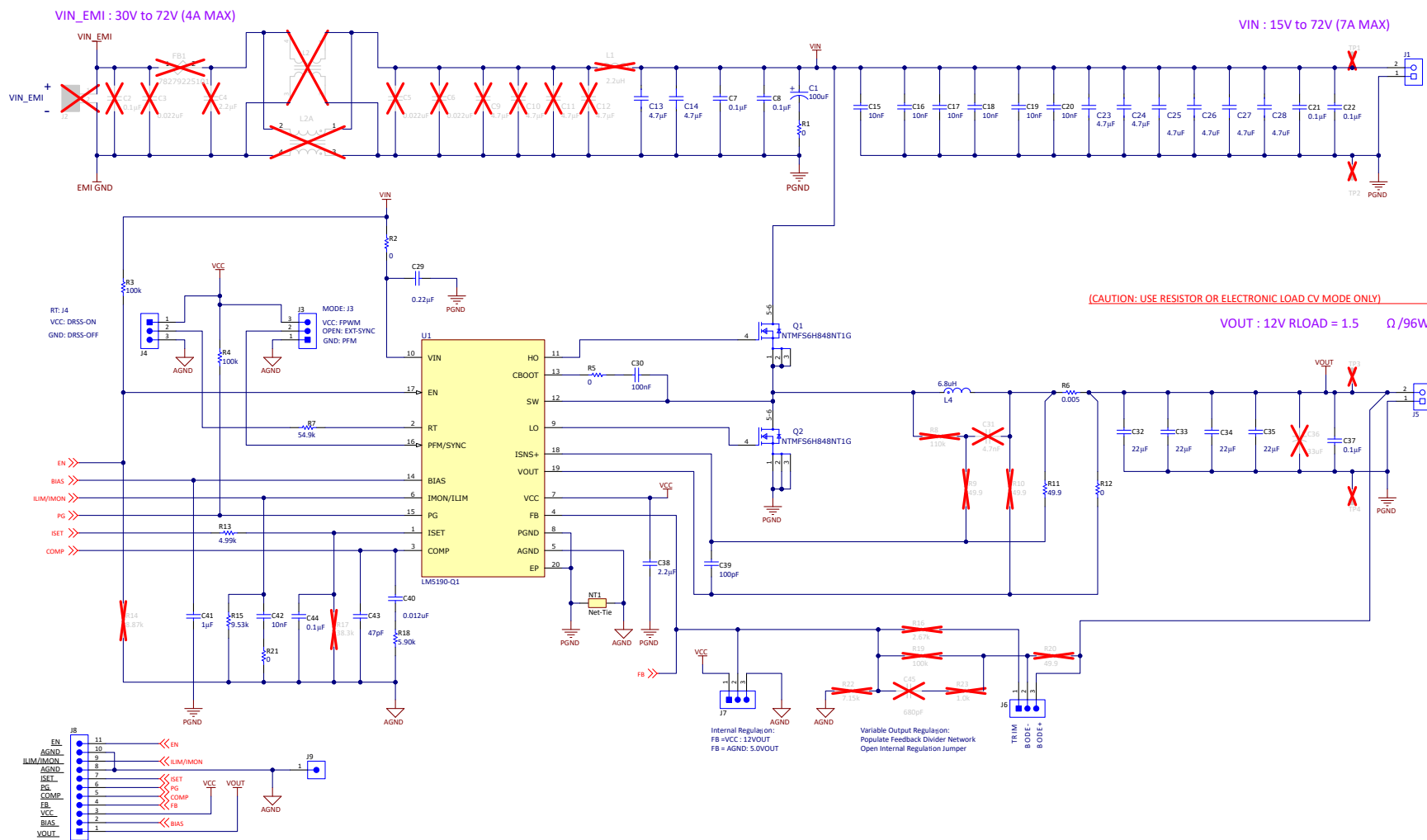# 4 Hardware Design Files

4.1 Schematic

Figure 4-1. EVM Schematic

4.2 PCB Layout

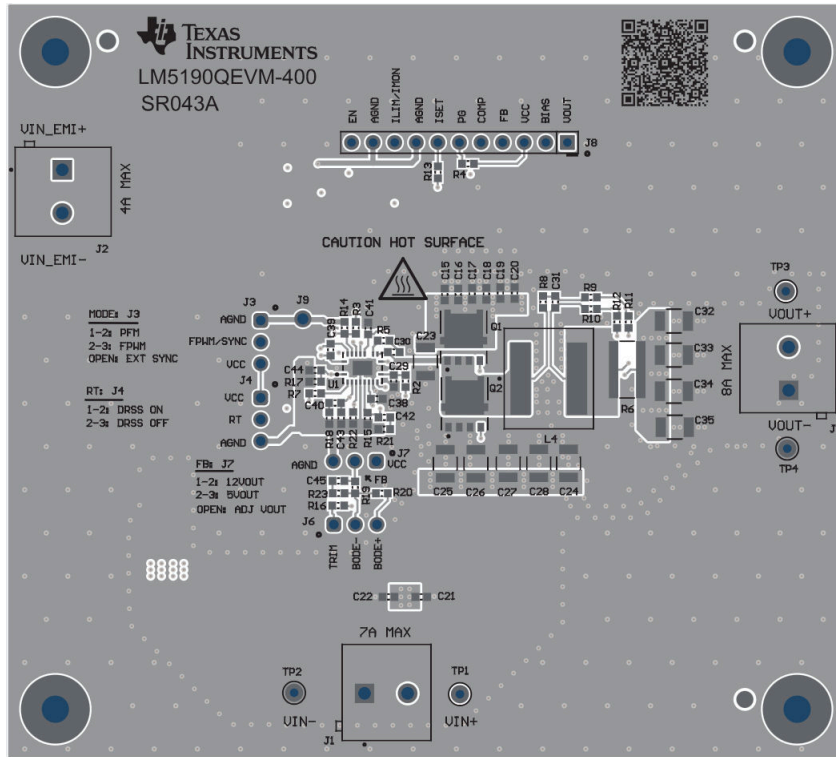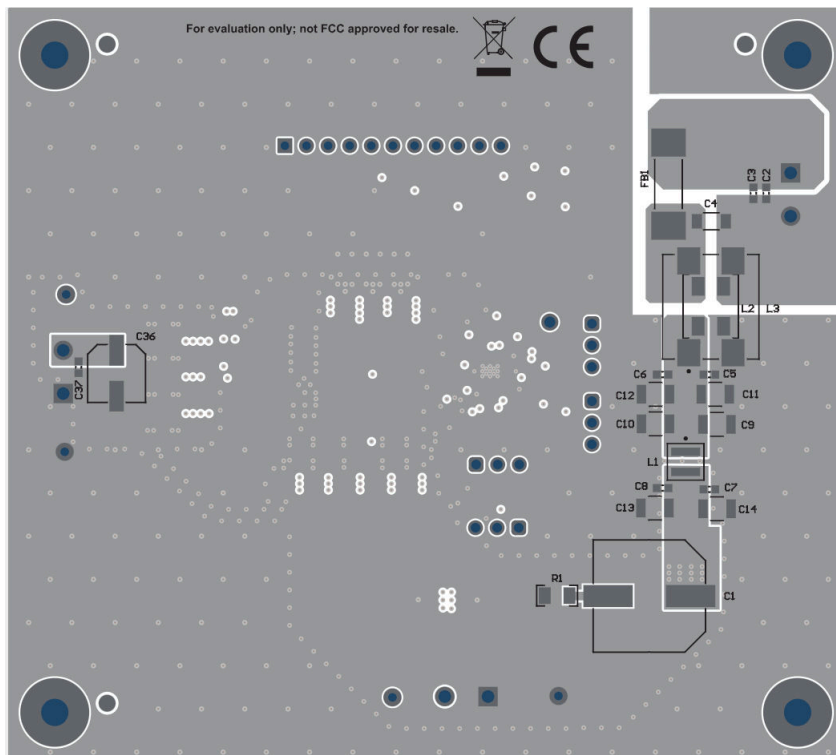LM5190 EVM uses a 6-layer PCB with 2-oz copper thickness.
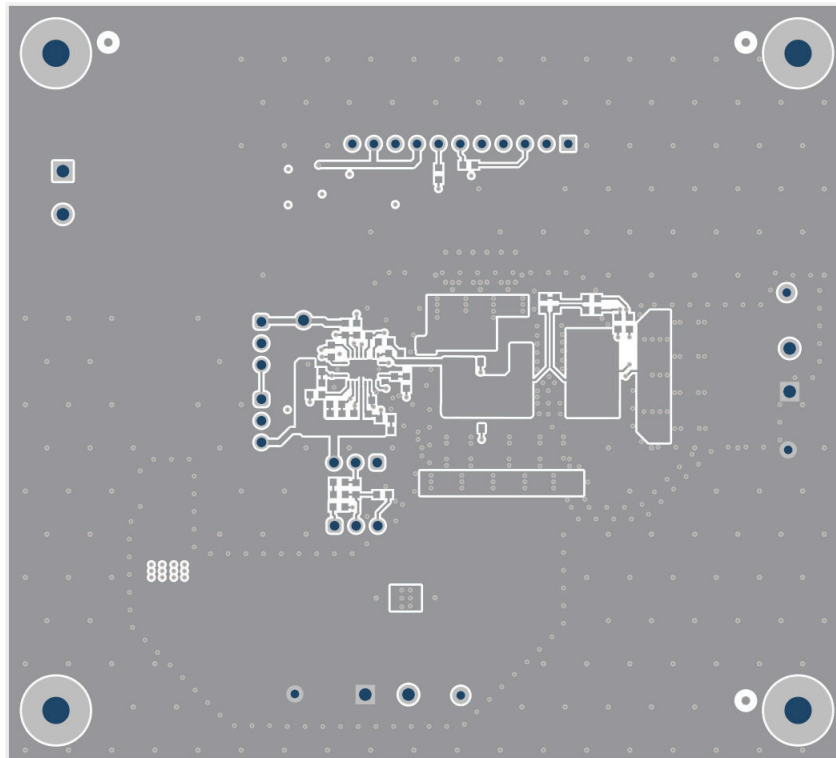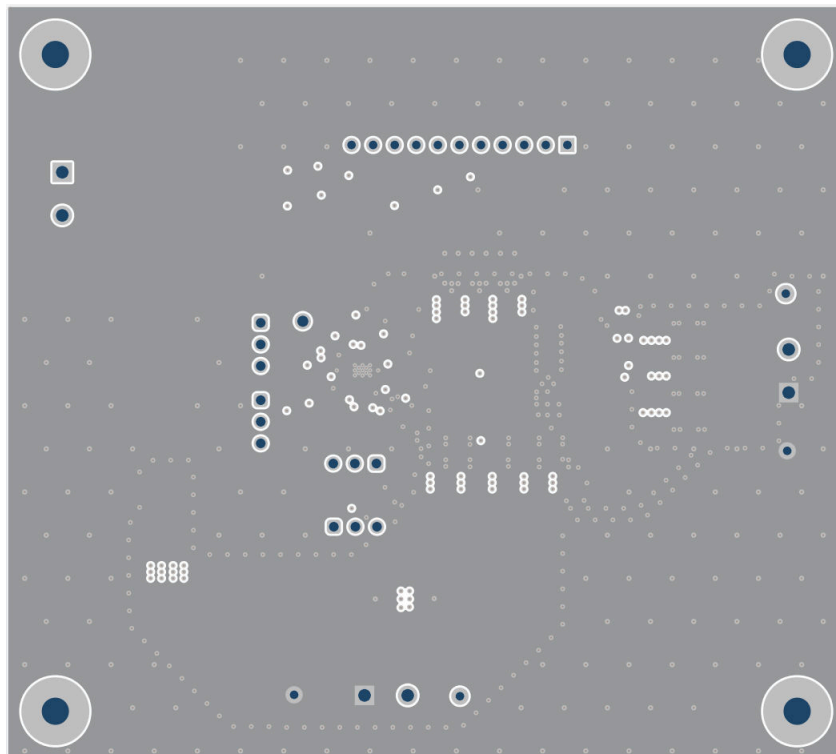

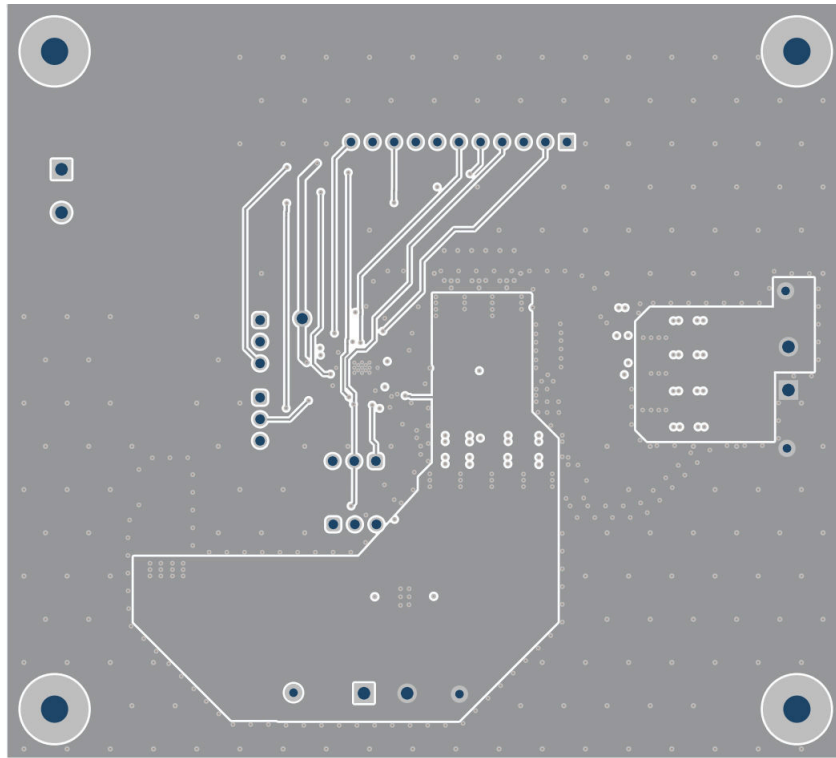**Figure 4-2. Top Components (Top View)**

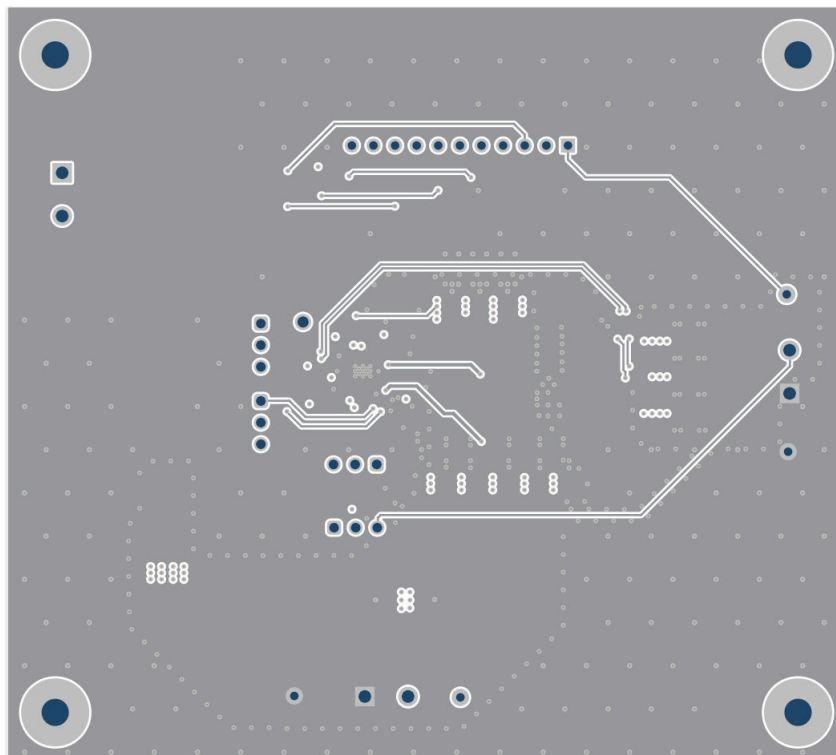**Figure 4-3. Bottom Components (Bottom View)**

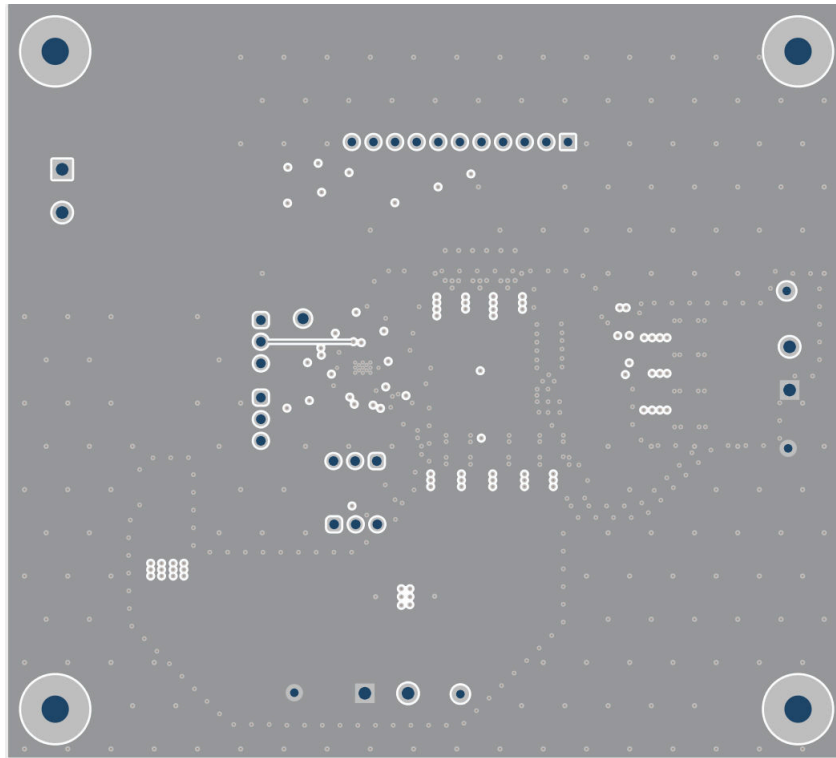**Figure 4-4. Top Layer Copper (Top View)**

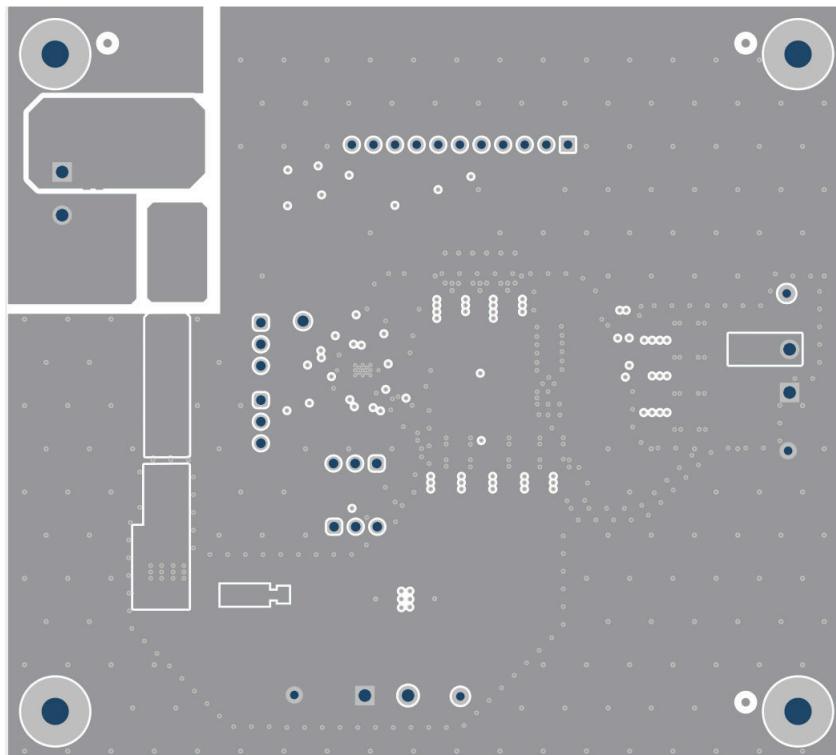
Figure 4-5. Layer 2 Copper (Top View)

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 (Top View)

4.3 Bill of Materials

Table 4-1. Bill of Materials

QTY	REF DES	DESCRIPTION	PART NUMBER	MFR
1	C1	CAP, AL, 100uF, 100V, +/- 20%, 0.33 ohm, SMD	EMVY101ATR101MKE0S	Chemi-Con
7	C7, C8, C21, C22, C30, C37, C44	CAP, CERM, 0.1µF, VAC/100 VDC,+/- 20%, X7R, AEC-Q200 Grade 1, 0603	HMK107B7104MAHT	Taiyo Yuden
8	C13, C14, C23, C24, C25, C26, C27, C28	4.7µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric)	CNC6P1X7R2A475K250AE	TDK
7	C15, C16, C17, C18, C19, C20, C42	CAP, CERM, 0.01µF, 100V,+/- 10%, X7R, 0603	885012206114	Wurth Elektronik
1	C29	CAP, CERM, 0.22µF, 100V,+/- 20%, X7S, AEC-Q200 Grade 1, 0603	HMK107C7224MAHTE	Taiyo Yuden
4	C32, C33, C34, C35	CAP, CERM, 22µF, 25V,+/- 10%, X7R, 1210	C1210C226K3RAC7800	Kemet
1	C38	CAP, CERM, 2.2uF, 16V, +/- 20%, X7S, AEC-Q200 Grade 1, 0603	CGA3E1X7S1C225M080AC	TDK
1	C39	CAP, CERM, 100pF, 100V, +/- 5%, C0G/NP0, 0603	GRM1885C2A101JA01D	MuRata
1	C40	CAP CER 0.012UF 25V C0G/NP0 0603	C0603C123J3GACTU	Kemet
1	C41	CAP, CERM, 1uF, 25V, +/- 10%, X7R, 0603	06033C105KAT2A	AVX
1	C43	CAP, CERM, 47pF, 50V,+/- 5%, C0G/NP0, AEC-Q200 Grade 0, 0603	CGA3E2NP01H470J080AA	TDK
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, 1"L #4-40 Nylon	1902E	Keystone
2	J1, J5	2 Position Wire to Board Terminal Block Horizontal with Board 0.200" (5.08mm) Through Hole	691253510002	Wurth Electronics
4	J3, J4, J6, J7	Header, 2.54mm, 3x1, Gold, TH	61300311121	Wurth Electronics
1	J8	Header, 100mil, 11x1, Gold, TH	TSW-111-07-G-S	Samtec
1	J9	Test point	1040	Keystone
1	L4	6.8µH Shielded Molded Inductor 14.8A 12.5mOhm Max Nonstandard	XGL1060-682MEC	Coilcraft
2	Q1, Q2	N-Channel 80V 13A (Ta) 57A (Tc) 3.7W (Ta) 73W (Tc) Surface Mount 5-DFN (5x6) (8-SOFL)	NTMFS6H848NT1G	onsemi
1	R1	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	RCA12060000ZSEA	Vishay-Dale
4	R2, R5, R12, R21	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL	Yageo
2	R3, R4	RES, 100 k, 1%, 0.1 W, 0603	RC0603FR-07100KL	Yageo
1	R6	RES, 0.005, 1%, 2 W, 2512 WIDE	FCSL64R005FER	Ohmite
1	R7	RES, 54.9 k, 1%, 0.1 W, 0603	RC0603FR-0754K9L	Yageo
1	R11	RES, 49.9, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	ERJ-3EKF49R9V	Panasonic
1	R13	RES, 4.99 k, 1%, 0.1 W, 0603	RC0603FR-074K99L	Yageo
1	R15	RES, 9.53 k, 1%, 0.1 W, 0603	RC0603FR-079K53L	Yageo
1	R18	RES, 5.90 k, 1%, 0.1 W, 0603	RC0603FR-075K9L	Yageo
4	SH-J1, SH-J2, SH-J3, SH-J4	Single Operation 2.54mm Pitch Open Top Jumper Socket	M7582-05	Harwin
1	U1	80V Synchronous Buck Controller with Constant Current Constant Voltage Regulation	LM5190-Q1	Texas Instruments

5 Additional Information

5.1 Trademarks
PowerPAD™ is a trademark of Texas Instruments.
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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 report
- 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

- *AN-1149 Layout Guidelines for Switching Power Supplies* application report
- *AN-1229 Simple Switcher PCB Layout Guidelines* application report
- *Constructing Your Power Supply – Layout Considerations Power Supply* design seminar
- *Low Radiated EMI Layout Made SIMPLE with LM4360x and LM4600x* application report
- Power House Blogs:
  - *High-Density PCB Layout of DC-DC Converters*

6.2.1.2 Thermal Design Resources

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

7 Revision History

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

Changes from Revision * (June 2024) to Revision A (November 2024)	Page
• Updated board image	1
• Changed V_{SUPPLY} to V_{LOAD} in Figure 3-2	6
• Added EMI filter information	10

18   *LM5190-Q1 CCCV Buck Controller Evaluation Module*   SLVUCY4A – JUNE 2024 – REVISED NOVEMBER 2024
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    1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

    2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

    2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

    2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:
EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3   *Regulatory Notices:*

3.1   *United States*

3.1.1   *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2   *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2   *Canada*

3.2.1   *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

   3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に 輸入される評価用キット、ボードについては、次のところをご覧ください。

     https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

   3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けて

いないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの

措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用 いただく。
2. 実験局の免許を取得後ご使用いただく。
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２４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.

IMPORTANT NOTICE AND DISCLAIMER