

Description

The LM5185-Q1 controller uses an external power MOSFET and has adjustable loop compensation and current limit. All these features bring flexibility and design optimization for power scaling, transformer design, and BOM optimization, as well as overall performance and solution cost. Other user programmabilities are also supported including the input UVLO with hysteresis, soft-start, and temperature compensation.

Get Started

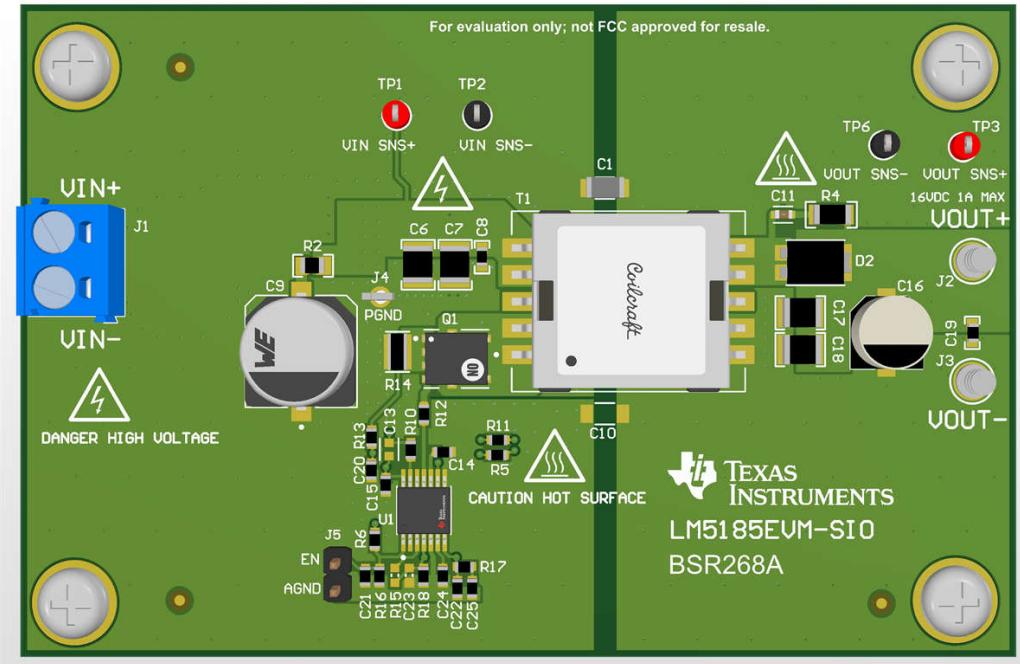
1. Order the EVM at ti.com.
2. Read this user's guide carefully.
3. Prepare the bench setup per instructions. Take cautions to prevent damage by ESD when handling the EVM.
4. Power up the EVM by following the recommended steps.
5. Run tests and measurements. Take cautions of high voltage and hot temperature produced by the EVM during test.

Features

- Wide input voltage range (default 20V to 60V, extendable 6V to 90V)
- Tight voltage regulation of the isolated output without opto-coupler: $16.4V \pm 1.5\%$
- Removal of the opto-coupler and transformer aux winding saves solution size and cost.
- Peak conversion efficiency $> 90\%$
- Programmable loop compensation, current limit, input UVLO, and thermal compensation allowing for flexible and optimal designs.

Applications

- Traction inverters
- Onboard charger (OBC)
- HEV/EV HVAC and heater
- Micro inverters
- Motor drives
- Battery Management Systems (BMS)
- Generic IGBT, MOSFET, GaN and SiC gate drivers
- PoE PD dc-dc converters
- Generic isolated bias power rails for industrial and telecom systems



1 Evaluation Module Overview

1.1 Introduction

The [LM5185-Q1](#) single-isolated-output (SIO) evaluational module (EVM), otherwise known as LM5185EVM-SIO, is designed to demonstrate the features and functionality of the LM5185-Q1 device. The device is a 100-V_{IN} Primary-Side-Regulated (PSR) flyback DC/DC controller based on sampling the primary winding voltage of the transformer to achieve tight output regulation and high efficiency, without using the opto coupler nor tertiary bias winding like in a conventional flyback converter.

This user's guide describes the characteristics and operation of the evalutaion module LM5185EVM-SIO. This document provides examples and instructions on how to use the evaluation module, and presents typical performance curves and key waveforms. Throughout this document, the terms of evaluation board, evaluation module, and EVM are synonymous with the LM5185EVM-SIO. This document also includes a schematic, reference printed circuit board (PCB) layout, and a complete bill of materials (BOM).

1.2 Kit Contents

[Table 1-1](#) details the contents of the EVM kit. Contact the TI Product Information Center at (972) 644-5580 if any component is missing. Download the latest versions of the related software on the TI website, www.ti.com.

Table 1-1. EVM Kit Contents

ITEM	QUANTITY
LM5185EVM-SIO	1

1.3 Specification

[Figure 1-1](#) shows the simplified schematic of the LM5185EVM-SIO circuit board. [Table 1-2](#) shows the specifications of the EVM in the factory default settings.

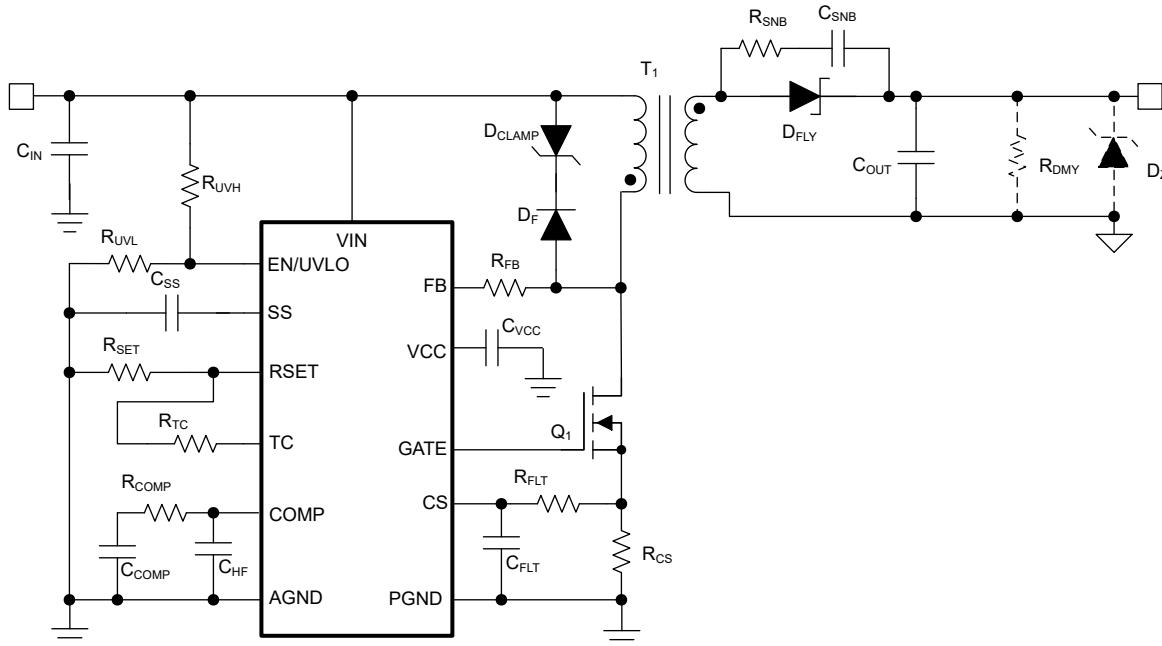


Figure 1-1. LM5185 PSR Flyback Converter Simplified Schematic

Table 1-2. Electrical Performance Characteristics

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS					
Input voltage range, V_{IN}		20	60		V
Input voltage turn on, V_{IN_ON}	Adjustable using EN/UVLO divider resistors		19		
Input voltage turnoff, V_{IN_OFF}			18		
Input current, operating with no load, I_{IN_NL}	$I_{OUT} = 0 \text{ A}$	$V_{IN} = 20 \text{ V}$	5.57		mA
		$V_{IN} = 60 \text{ V}$	3.32		
Input current, disabled, I_{IN_OFF} , excluding the external UVLO resistor leak current	$V_{EN} = 0 \text{ V}$, removing R6	$V_{IN} = 20 \text{ V}$	5.0		μA
		$V_{IN} = 40 \text{ V}$	10.0		
		$V_{IN} = 60 \text{ V}$	20.0		
OUTPUT CHARACTERISTICS					
Output voltage, V_{OUT}		16.154	16.400	16.646	V
Max output current, I_{OUT}	$V_{IN} = 20 \text{ V}$		1.0		A
			1.5		A
			1.8		A
Soft-start time, t_{SS}	$I_{OUT} = 1 \text{ A}$		25		ms
SYSTEM CHARACTERISTICS					
Switching Frequency	$V_{IN} = 48 \text{ V}$, $I_{OUT} = 0.5 \text{ A}$		350		kHz
Half-load efficiency, η_{HALF}	$I_{OUT} = 0.5 \text{ A}$	$V_{IN} = 20 \text{ V}$	90.2		
		$V_{IN} = 40 \text{ V}$	84.3		
		$V_{IN} = 60 \text{ V}$	82.0		
Full load efficiency, η_{FULL}	$I_{OUT} = 1.0 \text{ A}$	$V_{IN} = 20 \text{ V}$	90.5		
		$V_{IN} = 40 \text{ V}$	89.9		
		$V_{IN} = 60 \text{ V}$	86.9		
Isolation rating(3)	RMS voltage		1500		V
LM5180 junction temperature, T_J			-40	150	$^{\circ}\text{C}$

1.4 Device Information

The factory default settings of the EVM allow the operation with an input voltage range from 20 V to 60 V. The device produces a single isolated output voltage of 16.4 V $\pm 1\%$ @ 1 A load, and achieves $> 90\%$ peak efficiency. Fine-tuning of the output voltage can be realized by adjusting the external resistor values at the FB pin. In addition, the users can modify the EVM to enable the operation under a V_{IN} down to 6 V with derated output current of 0.4A by changing the EN/UVLO set point. Further lower input voltage down to 4.5V is supported by the LM5185-Q1 but the EVM requires a different transformer. However, the maximum V_{IN} voltage of the EVM can be increased to 90 V if the power MOSFET is changed to a 150 V or higher rated device, and if the input bulk capacitor is replaced with at least a 100 V rated part. Multiple isolated output can also be supported by the LM5185-Q1 but requires a different transformer. Please refer to the [Quick Start Design Calculator](#) to help design.

Refer to TI product data sheet [SNVSBT4](#) for more detailed information of the LM5185-Q1 PSR flyback controller.

2 Hardware

2.1 Setup

Figure 2-1 shows the diagram of EVM bench test setup. Refer to [Section 2.2](#) and [Section 2.3](#) in this user's guide for detailed information of headers, jumpers and test points. Refer to [Section 2.4](#) for the setup assembly and test procedure. Refer to [Section 2.5](#) for the important notice on safety concerns when handling the EVM.

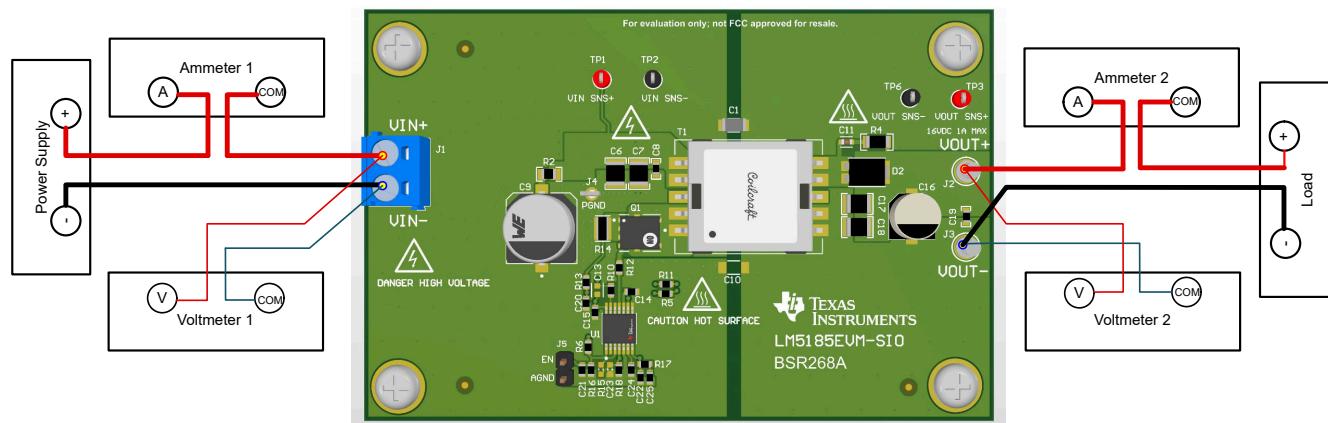


Figure 2-1. EVM Test Setup

The test setup consists the following instruments in addition to the EVM board.

- **Power Supply:** The input dc voltage source capable of at least 0-80-V and 2 A.
- **Load:** The load must be electronic constant-resistance (CR) or constant-current (CC) mode load, capable of 0 Adc to 2 Adc up to 20 V. For a no-load input current measurement, disconnect the electronic load as the load can draw a small residual current.
- **Multimeters:**
 - **Voltmeter 1:** Input voltage at VIN+ to VIN-. Set voltmeter to an input impedance of 100 MΩ.
 - **Voltmeter 2:** Output voltage at VOUT+ to VOUT-. Set voltmeter to an input impedance of 100 MΩ.
 - **Ammeter 1:** Input current. Set ammeter to 1-second aperture time.
 - **Ammeter 2:** Output current. Set ammeter to 1-second aperture time
- **Oscilloscope:** With the scope set to 20-MHz 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. Place the oscilloscope probe tip on the positive terminal of the output capacitor, holding the ground barrel of the probe through the ground lead to the negative terminal of the capacitor. 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.

2.2 Header Information

[Table 2-1](#) lists the header information of the EVM.

Table 2-1. Header Information

HEADER	SIGNAL	DESCRIPTION
J1-1	VIN+	Voltage source input port.
J1-2	VIN-	Voltage source input return.
J2	VOUT+	Output voltage port.
J3	VOUT-	Output voltage return port, and also the isolated ground reference ISO-GND.
J4	PGND	Primary side power ground reference.
J5-1	EN/UVLO	Enable and UVLO control signal. Closing J5-1 and J5-2 disables the EVM.
J5-2	AGND	Analog signal reference ground.

2.3 Test Points

The EVM has a variety of test points available for measuring and debugging purposes. [Table 2-2](#) explains the purpose of each test point.

Table 2-2. EVM Test Points

TEST POINT	SIGNAL	DESCRIPTION
TP1	VIN	PSR Flyback dc-dc stage input voltage
TP2	PGND	Primary side power ground reference
TP3	VOUT	Isolated output voltage
TP4	COMP	Compensation circuit node for the error amplifier
TP5	RSET	Output voltage set pin
TP6	ISO-GND	Isolated output ground reference

2.4 Assembly Instructions

Refer to [Section 2.5](#) of this user's guide for the important notice on safety concerns when handling the EVM. The following are the recommended instructions for the EVM test setup assembly.

Input Connections

- Prior to connecting the DC input source, set the current limit of the input supply to 100 mA maximum. Verify the input source is initially set to 0 V and connected to the VIN+ and VIN- connection points, as shown in [Figure 2-1](#). An additional input bulk capacitor is recommended to provide damping if long input lines are used.
- Connect Voltmeter 1 at VIN+ and VIN- connection points to measure the input voltage.
- Connect Ammeter 1 to measure the input current and set to at least 1-second aperture time.

Output Connections

- Connect electronic load to VOUT+ and VOUT- connection points as shown in [Figure 2-1](#). Set the load to constant-resistance mode or constant-current mode at 0 A before applying input voltage.
- Connect Voltmeter 2 at VOUT+ and VOUT- connection points to measure the output voltage.
- Connect Ammeter 2 measure the output current.

Test Procedure

- Set up the EVM as described above.
- Set load to constant resistance or constant current mode and to sink 10 mA.
- Increase input source from 0 V to 20 V; use voltmeter 1 to measure the input voltage.
- Increase the current limit of the input supply to 1000 mA.
- Use voltmeter 2 to measure the output voltage, vary the load from 10 mA to 1000 mA DC; VOUT must remain within the load regulation specification.
- Set the load current to 500 mA (50% rated load) and vary the input source voltage from 20 V to 60 V; VOUT must remain within the line regulation specification.
- Use the oscilloscope to probe different signals of interest. Be careful of the probe ground reference.
- Decrease load to 10 mA. Decrease input source voltage to 0 V.
- Shut down both the input source and load, and then the voltmeters and ammeters.

2.5 Best Practices

Please take caution when handling the EVM. Operating the EVM board with up to 60 V_{IN} can generate >75 V voltage at certain circuit nodes as marked by the high voltage symbol on the PCB. Operating the EVM board with the maximum load can generate hot spots in certain areas of the PCB as marked by the hot surface symbols. Please read the following notices carefully.



Always follow TI's set-up and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center <http://support.ti.com> for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions can result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed-circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

• Work Area Safety:

- Maintain a clean and orderly work area.
- Qualified observers must be present anytime circuits are energized.
- Effective barriers and signage must be present in the area where the TI HV EVM and interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
- All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50 V_{RMS}/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
- Use a stable and non-conductive work surface.
- Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.

• Electrical Safety:

As a precautionary measure, it is always a good engineering practice to assume that the entire EVM can have fully accessible and active high voltages.

- De-energize the TI HV EVM and all inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
- With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
- When EVM readiness is complete, energize the EVM as intended.

WARNING

WARNING: While the EVM is energized, never touch the EVM or its electrical circuits as the EVM and circuits can be at high voltages capable of causing electrical shock hazard.

• Personal Safety:

- Wear personal protective equipment, for example, latex gloves and/or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.

• Limitation for Safe Use:

- EVMs are not to be used as all or part of a production unit.

Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training, and is designed to operate from an AC power supply or a high-voltage DC supply. Please read this user guide and the safety-related documents that come with the EVM package before operating this EVM.



CAUTION

Do not leave the EVM powered when unattended.



WARNING

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



WARNING

High Voltage! Electric shock is possible when connecting board to live wire. Board must be handled with care by a professional.

For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

3 Implementation Results

3.1 Performance Data and Results

Figure 3-1 through Figure 3-8 presents typical performance curves for the LM5185EVM-SIO. Because actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and the curves can differ from actual field measurements.

3.1.1 Conversion Efficiency

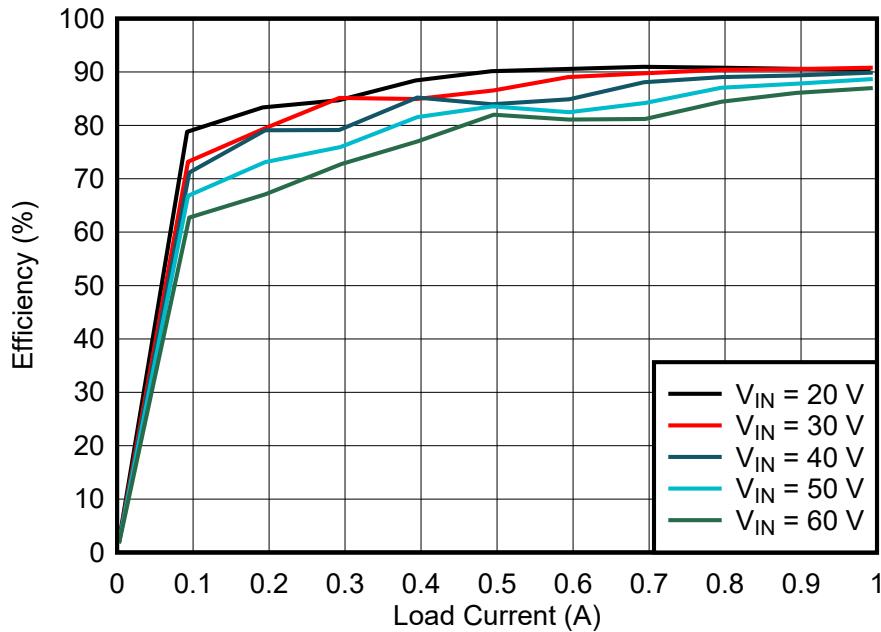


Figure 3-1. EVM Efficiency vs. Load and Input Voltage

3.1.2 Output Voltage Regulation

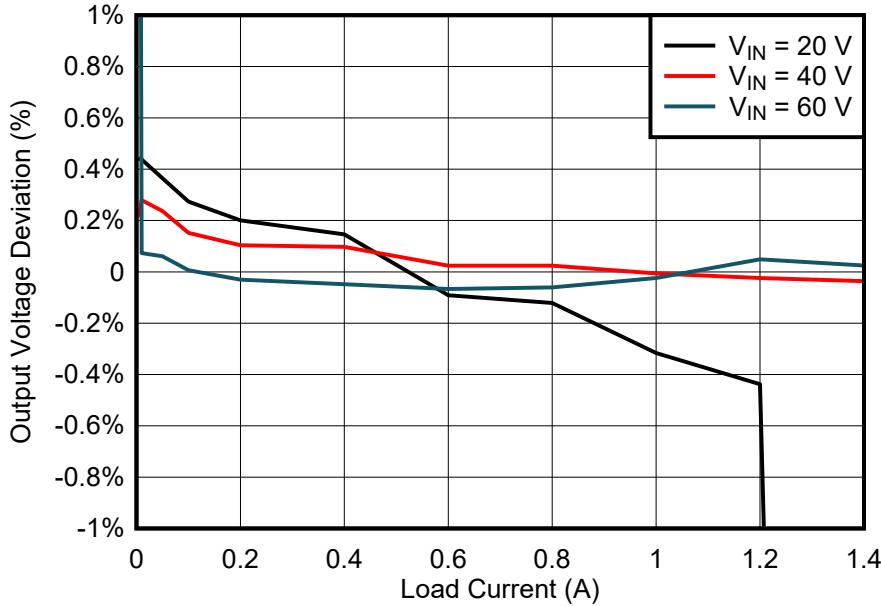
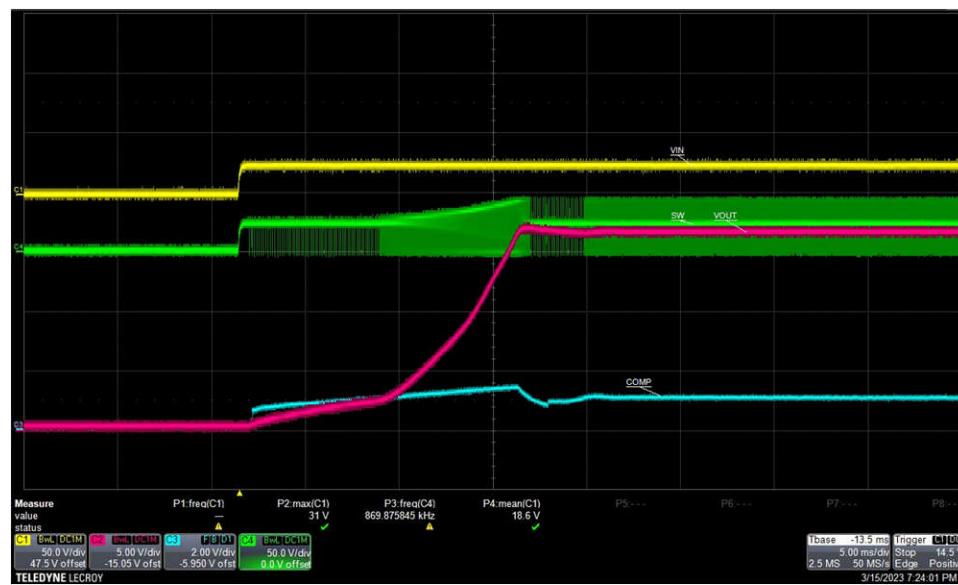


Figure 3-2. EVM Output Voltage Regulation vs Load and Input Voltage

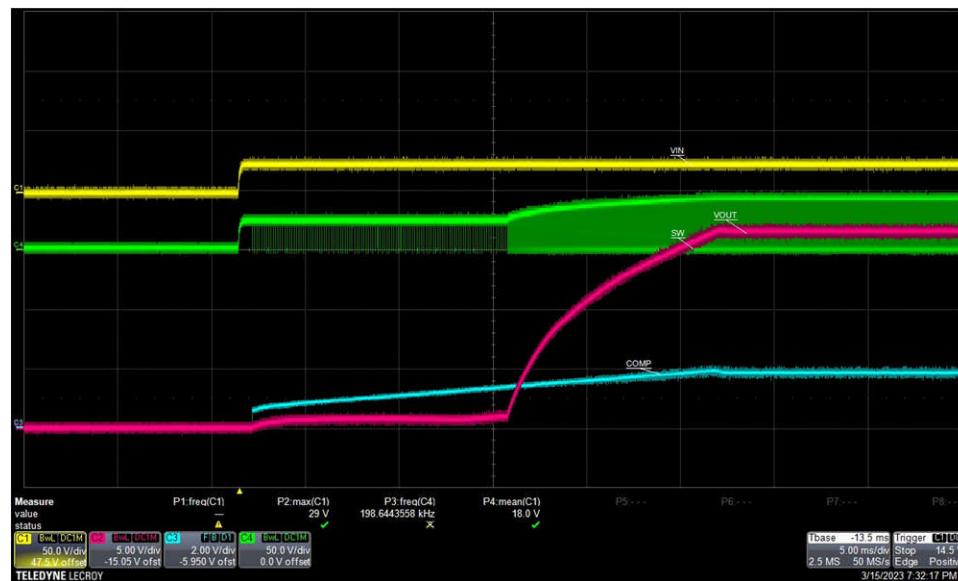
3.1.3 Operating Waveforms

3.1.3.1 Start-up



C1=Vin; C2=Vout; C3=COMP; C4=SW

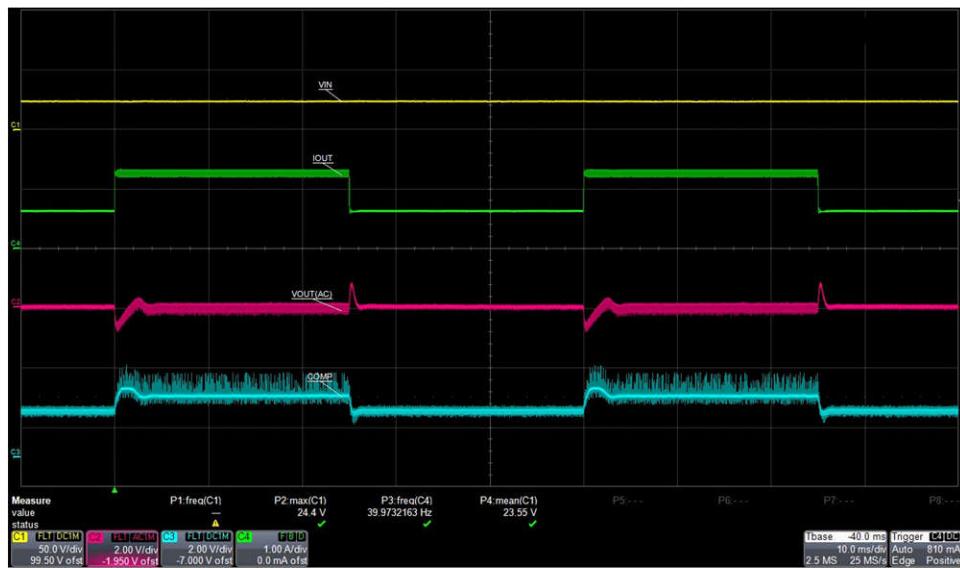
Figure 3-3. Start-up Under No Load: Vin=24V, Iout=0A



C1=Vin; C2=Vout; C3=COMP; C4=SW

Figure 3-4. Start-up Under Full Load: Vin=24V, Iout=1A

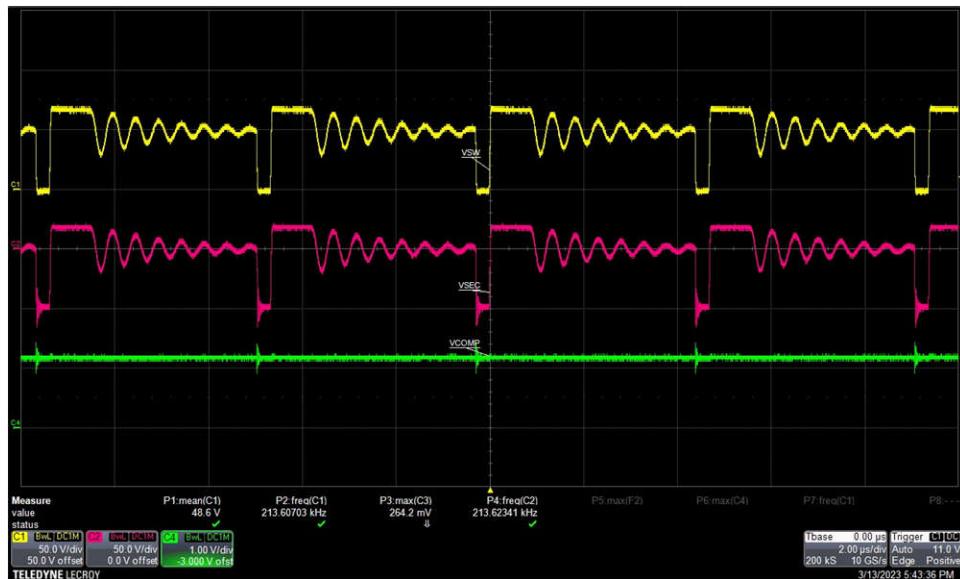
3.1.3.2 Load Transient Response



C1=Vin; C2=Vout (ac coupled); C3=Vcomp; C4=Iout

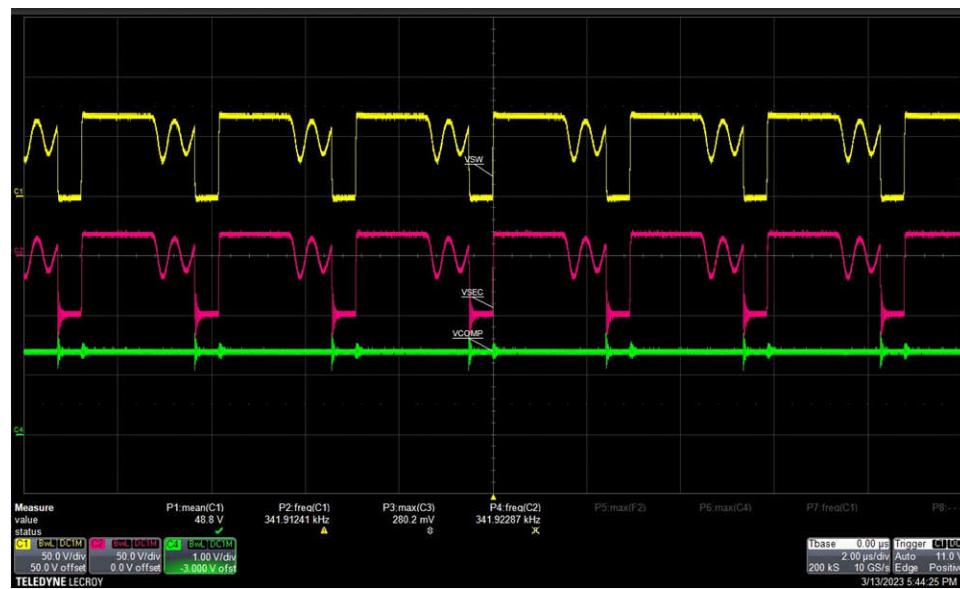
Figure 3-5. Load Transient Response: Vin=24V, 0.625A to 1.25A Load Transients

3.1.3.3 Switching



C1=SW; C2=Vsec; C3=Vcomp

Figure 3-6. FFM Operation: VIN=48 V, Iout= 0.1A



C1=SW; C2=Vsec; C4=Vcomp

Figure 3-7. DCM Operation: Vin=48V, Iout=0.5A

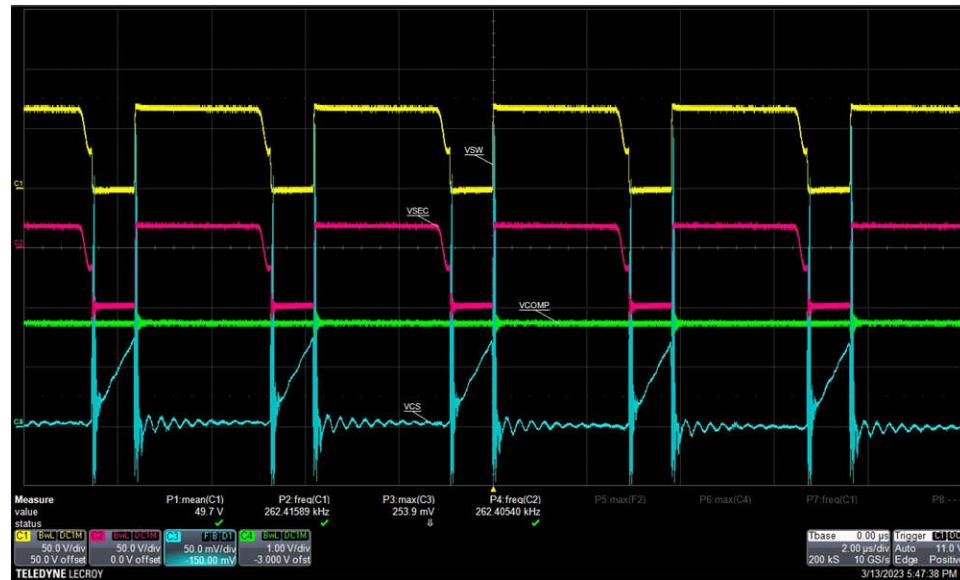


Figure 3-8. BCM Operation: Vin=48V, Iout=1.0A

3.2 Thermal Performance

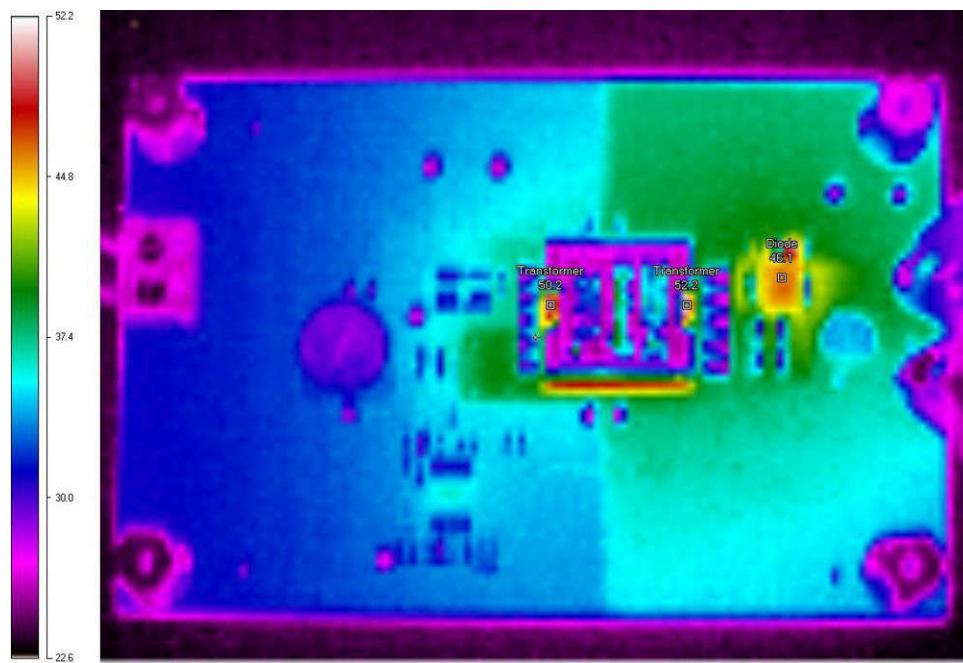


Figure 3-9. EVM Thermal Image. Vin=48V, Iout=1.0A

4 Hardware Design Files

4.1 Schematic

Figure 4-1 shows the complete schematic of the EVM.

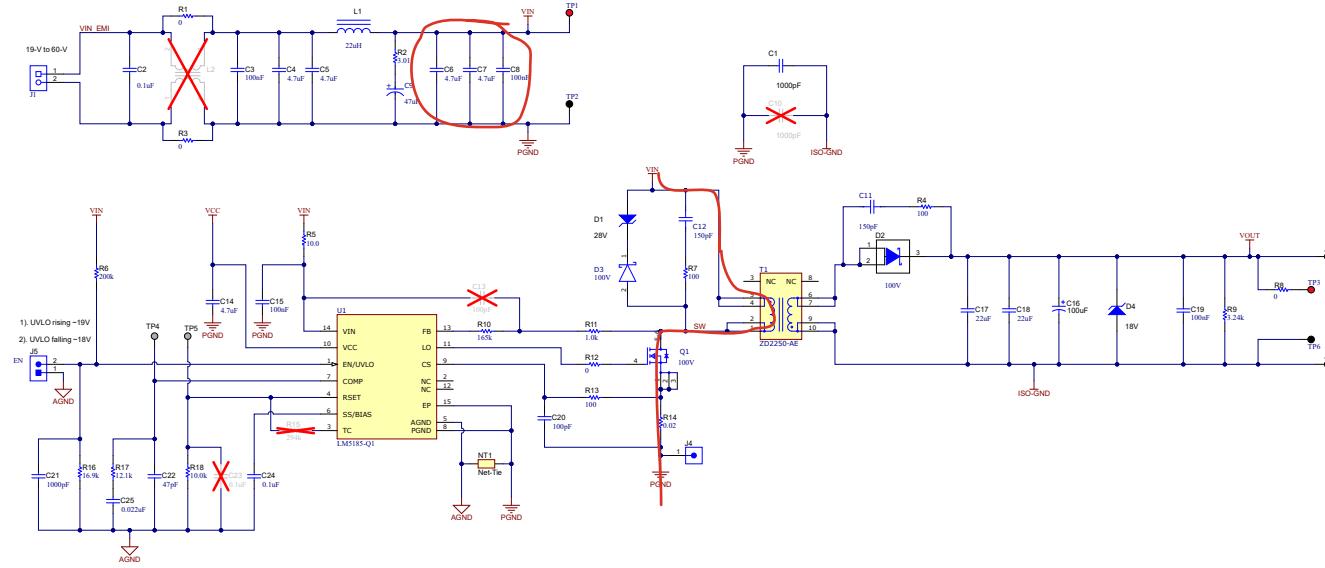


Figure 4-1. LM5185EVM-SIO Schematic

4.2 PCB Layout

Figure 4-2 through Figure 4-7 show the printed circuit board layout of the EVM.

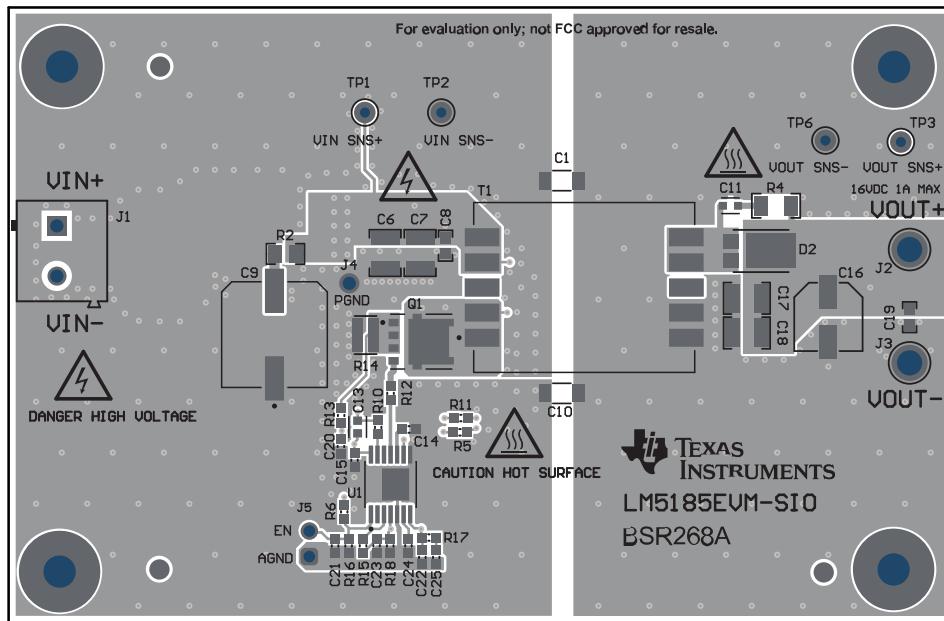


Figure 4-2. Top Layer Silkscreen (Top View)

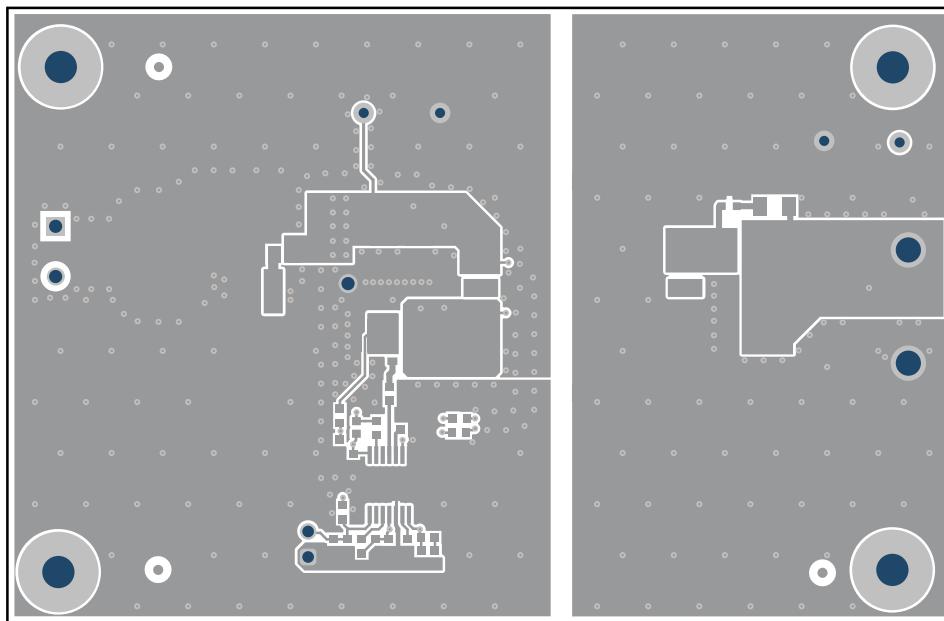


Figure 4-3. Top Layer Layout (Top View)

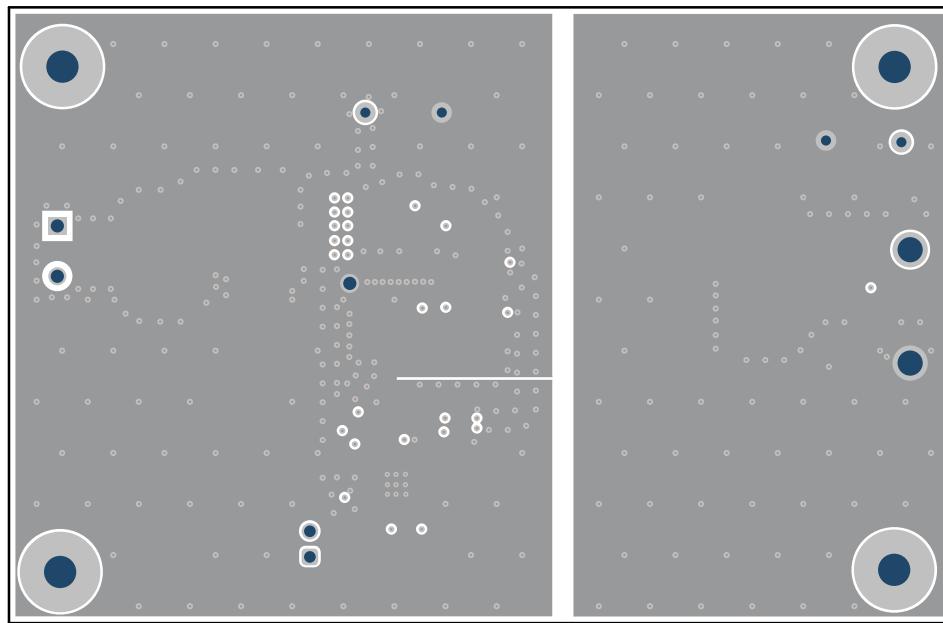


Figure 4-4. Mid Layer 1 Layout (Top View)

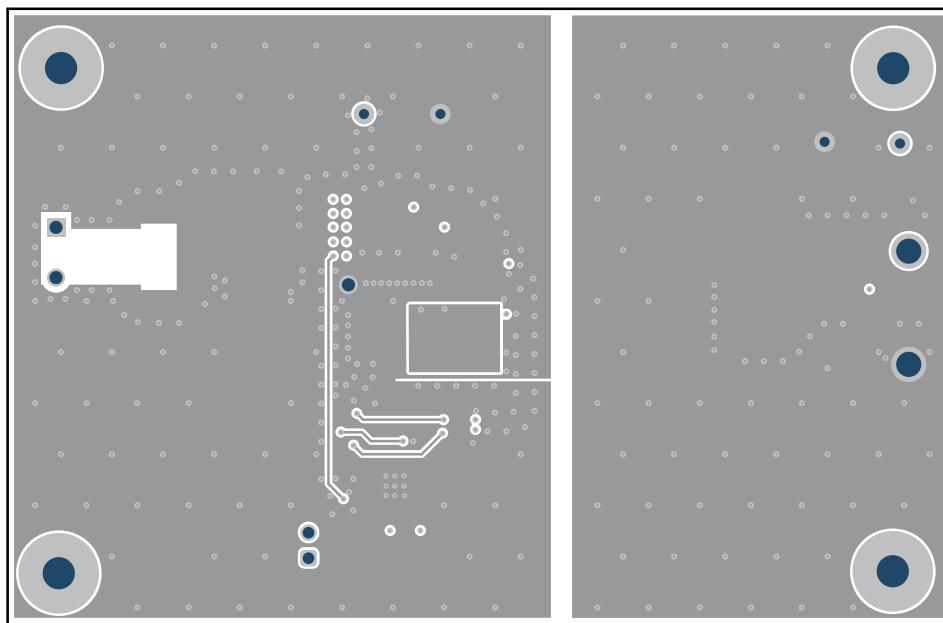


Figure 4-5. Mid Layer 2 Layout (Top View)

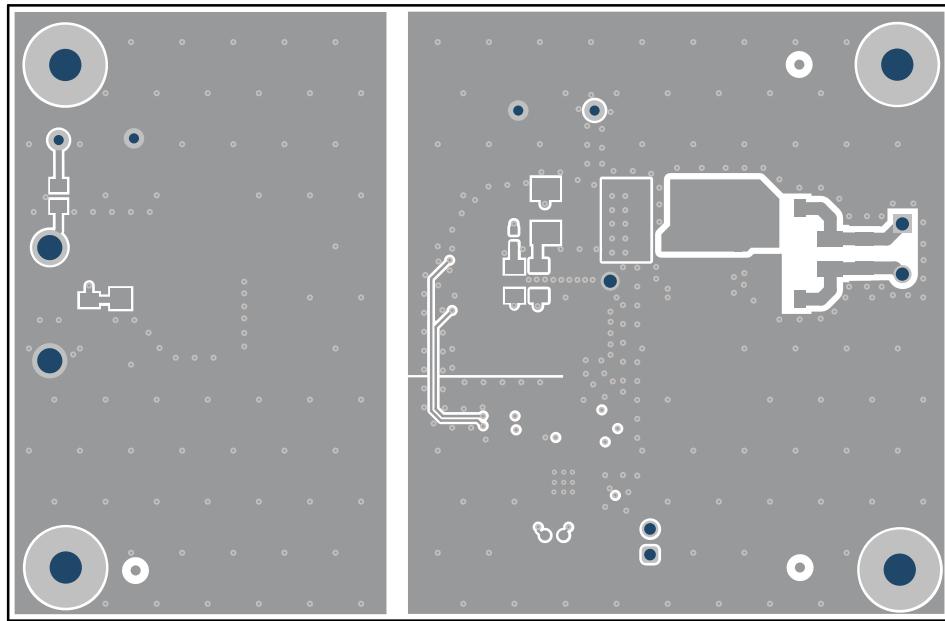


Figure 4-6. Bottom Layer Layout (Bottom View)

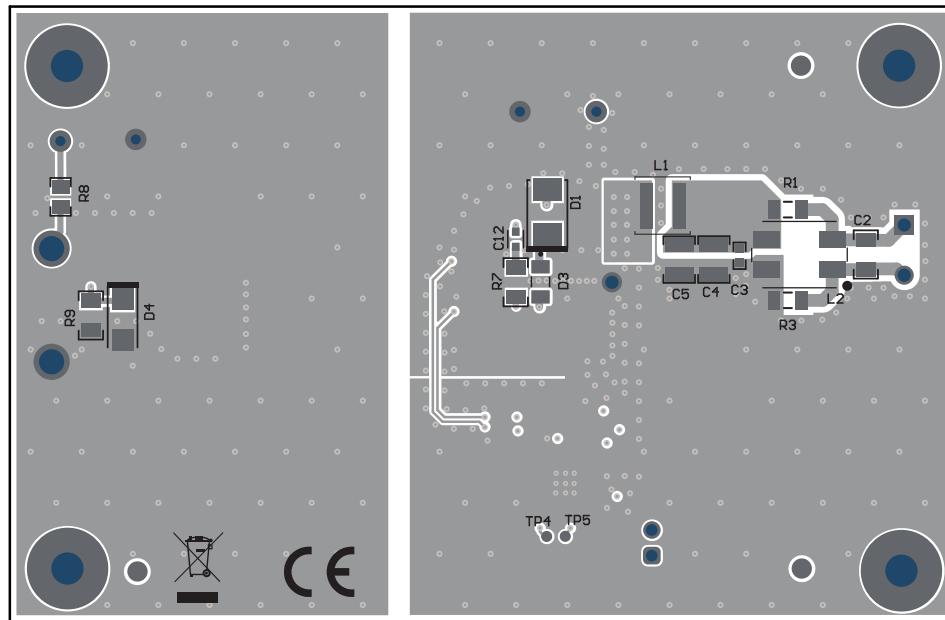


Figure 4-7. Bottom Layer Silkscreen (Bottom View)

4.3 Bill of Materials (BOM)

Table 4-1 lists the LM5185EVM-SIO bill of materials (BOM).

Table 4-1. Bill of Materials

Designator	Qty	Description	PartNumber	Manufacturer
C1	1	CAP, CERM, 1000 pF, 2000 V, +/- 10%, X7R, 1206_190	202R18W102KV4E	Johanson Technology
C2	1	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 1206	GRM319R72A104KA01D	MuRata
C3, C8, C15, C19	4	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X7R, 0603	GRM188R72A104KA35D	MuRata
C4, C5, C6, C7	4	CAP, CERM, 4.7 uF, 100 V, +/- 10%, X7S, 1210	C3225X7S2A475K200AB	TDK
C9	1	Aluminum Electrolytic Capacitor 47uF 20% 80 V 10.3x10.3x10.5mm SMT	865081757008	Wurth Electronics
C11, C12	2	0603 150 pF 100 V ± 5 % Tolerance C0G/NP0 SMT Multilayer Ceramic Capacitor	06031A151JAT2A	KYOCERA AVX
C14	1	CAP, CERM, 4.7 uF, 16 V, +/- 10%, X7R, 0603	GRM188Z71C475KE21D	MuRata
C16	1	CAP, AL, 100 uF, 25 V, +/- 20%, 0.34 ohm, AEC-Q200 Grade 2, SMD	EEE-FK1E101XP	Panasonic
C17, C18	2	CAP, CERM, 22 uF, 25 V, +/- 10%, X7R, 1210	GRM32ER71E226KE15L	MuRata
C20	1	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H101JA01D	MuRata
C21	1	CAP, CERM, 1000 pF, 100 V, +/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	GCM1885C2A102JA16D	MuRata
C22	1	CAP, CERM, 47 pF, 50 V, +/- 5%, C0G/NP0, AEC-Q200 Grade 0, 0603	CGA3E2NP01H470J080AA	TDK
C24	1	CAP, CERM, 0.1 uF, 16 V, +/- 5%, X7R, 0603	C0603C104J4RACTU	Kemet
C25	1	CAP, CERM, 0.022 uF, 25 V, +/- 10%, X7R, 0603	C0603C223K3RACTU	Kemet
D1	1	Diode, Zener, 28 V, 5 W, SMB	SMBJ5362B-TP	Micro Commercial Components
D2	1	Diode, Schottky, 100 V, 5 A, PowerDI5	SDT5H100LP5-7	Diodes Inc.
D3	1	Diode 100 V 1 A Surface Mount SOD-123H	ACDBMT1100-HF	Comchip Technology
D4	1	Diode, Zener, 18 V, 1 W, AEC-Q101, SMA	SMAZ18-13-F	Diodes Inc.
L1	1	Inductor, Shielded, Composite, 22 uH, 3.4 A, 0.1 ohm, SMD	XAL5050-223MEB	Coilcraft
Q1	1	N-Channel 100 V 8.4A (Ta), 31 A (Tc) 3.6W (Ta), 49 W (Tc) Surface Mount 5-DFN (5x6) (8-SOFL)	NVMFS021N10MCLT1G	Onsemi
R1, R3	2	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	ERJ-8GEY0R00V	Panasonic
R2	1	RES, 3.01, 1%, 0.125 W, 0805	RC0805FR-073R01L	Yageo America
R4, R7	2	RES, 100, 1%, 0.25 W, AEC-Q200 Grade 0, 1206	ERJ-8ENF1000V	Panasonic
R5	1	RES, 10.0, 1%, 0.1 W, 0603	RC0603FR-0710RL	Yageo
R6	1	RES, 200 k, 1%, 0.1 W, 0603	RC0603FR-07200KL	Yageo
R8	1	RES, 0, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	ERJ-6GEY0R00V	Panasonic
R9	1	RES, 3.24 k, 1%, 0.25 W, AEC-Q200 Grade 0, 1206	ERJ-8ENF3241V	Panasonic
R10	1	RES, 165 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603165KFKEA	Vishay-Dale
R11	1	RES, 1.0 k, 5%, 0.1 W, 0603	RC0603JR-071KL	Yageo
R12	1	RES, 0, 5%, 0.1 W, 0603	RC0603JR-070RL	Yageo
R13	1	RES, 100, 1%, 0.1 W, 0603	RC0603FR-07100RL	Yageo
R14	1	RES, 0.02, 1%, 1 W, 0612	PRL1632-R020-F-T1	Susumu Co Ltd
R16	1	RES, 16.9 k, 1%, 0.1 W, 0603	RC0603FR-0716K9L	Yageo
R17	1	RES, 12.1 k, 1%, 0.1 W, 0603	RC0603FR-0712K1L	Yageo
R18	1	RES, 10.0 k, 1%, 0.1 W, 0603	RC0603FR-0710KL	Yageo

Table 4-1. Bill of Materials (continued)

Designator	Qty	Description	PartNumber	Manufacturer
T1	1	Flyback Transformer, 12 μ H, 4.1A Isat, 1 : 1 turns ratio, EFD15 10PIN SMD	ZD2250-AE	Coilcraft
U1	1	100-VIN PSR Flyback Automotive DC/DC Controller With Low IQ and Low EMI, HTSSOP14	LM5185-Q1	Texas Instruments

5 Compliance Information

5.1 Compliance and Certifications

LM5185EVM-SIO EU Declaration of Conformity (DoC) for Restricting the Use of Hazardous Substances (RoHS) ([SSZQR78](#))

6 Additional Information

6.1 Trademarks

All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

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 DEGRADATION 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 isotope 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/lsts/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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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。

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西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsts/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, INDEMNITY 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.

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