EVM User's Guide: LMR71915EVM-FLBK

LMR71915 Fly-Buck™ Converter Evaluation Module

Description

The LMR71915EVM-FLBK is a Fly-Buck™ converter that uses the LMR71915FDDAR to produce a regulated 12V output capable of supplying a 625mA load on the primary side of the transformer with a switching frequency of 500kHz. A reflected output of 12V, providing up to 625mA, is available on the secondary side of the transformer. The LMR71915FDDAR is a synchronous, buck converter with a wide input voltage range, integrated power MOSFETs, overcurrent protection, and precision enable. The device is rated to operate over a junction temperature range of –40°C to +150°C.

Get Started

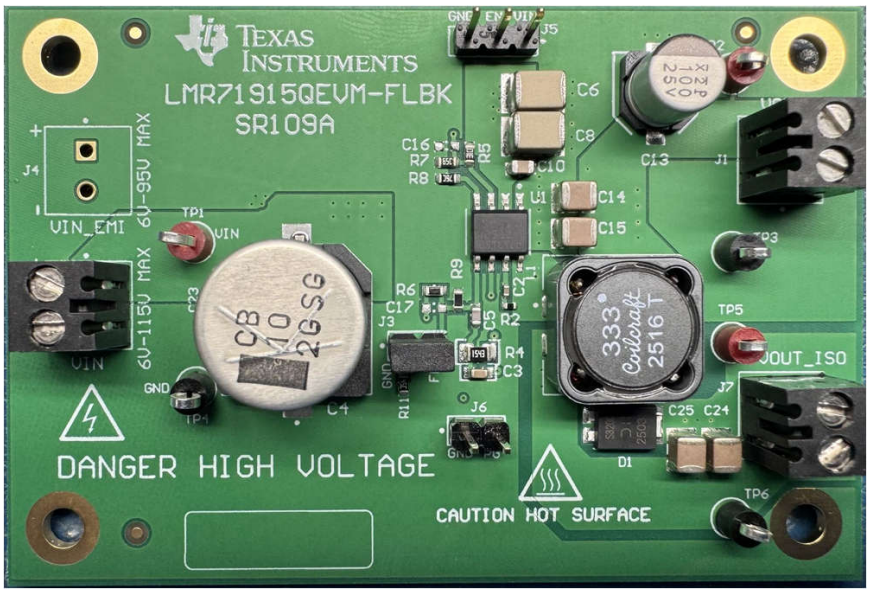
1. Order the LMR71915EVM-FLBK at ti.com.
2. Read this user's guide carefully.
3. Prepare the bench setup per instructions. Take precautions to prevent damage by ESD when handling the EVM.
4. Power up the EVM by following the recommended steps.
5. Run tests and measurements. Take precaution of high voltage and hot temperature produced by the EVM during test.

Features

- Wide input voltage range from 36V to 115V
- Fixed 3ms soft start
- COT mode control architecture
- Peak and valley current-limit protection
- FPWM mode for Fly-Buck converter capability
- SOIC-8 package for ease of use

Applications

- Communications - brick power module
- Industrial battery pack (≥ 10S)
- Battery pack - e-bike, e-scooter, LEV
- Motor drives, drones
- Factory automation - PLC
- Grid infrastructure - solar
- Generic isolated bias supplies in industrial, automotive, and telecom systems



1 Evaluation Module Overview

1.1 Introduction

The LMR71915 Fly-Buck converter evaluation module (EVM), also known as LMR71915EVM-FLBK, is configured to deliver a regulated 12V output, with 0.625A at 500kHz switching frequency, and an additional 12V floating output also capable of 0.625A. The LMR71915 uses a COT control architecture, with input voltage feedforward to provide a constant frequency regulator with tightly regulated output voltage. This type of control requires adequate voltage ripple at the FB input to achieve stable regulation. The LMR71915EVM-FLBK is set up with type III ripple injection to minimize the output voltage ripple while making sure there is a stable regulator. The LMR71915EVM-FLBK also provides the option to use type I or type II ripple injection. See also *LMR719xx 1.5A, 0.75A, 115V, Step-Down Converter With Fly-Buck™ Converter Capability* data sheet for more information.

This user's guide describes the characteristics and operation of the EVM. This user's guide also provides examples and instructions on how to use the EVM, and presents typical performance curves and key waveforms. Throughout this document, the terms of evaluation board, evaluation module, and EVM are synonymous with the LMR71915EVM-FLBK. This document also includes the schematic, reference printed circuit board (PCB) layout, and the bill of materials (BOM).

1.2 Kit Contents

The following table details the contents of the EVM kit. Contact the TI Product Information Center at (972) 644-5580 if any component is missing.

Table 1-1. EVM Kit Contents

ITEM	QUANTITY
LMR71915EVM-FLBK	1

1.3 Specification

Figure 1-1 shows the simplified schematic of the LMR71915EVM-FLBK circuit board. Table 1-2 shows the specifications of the EVM in the factory default settings.

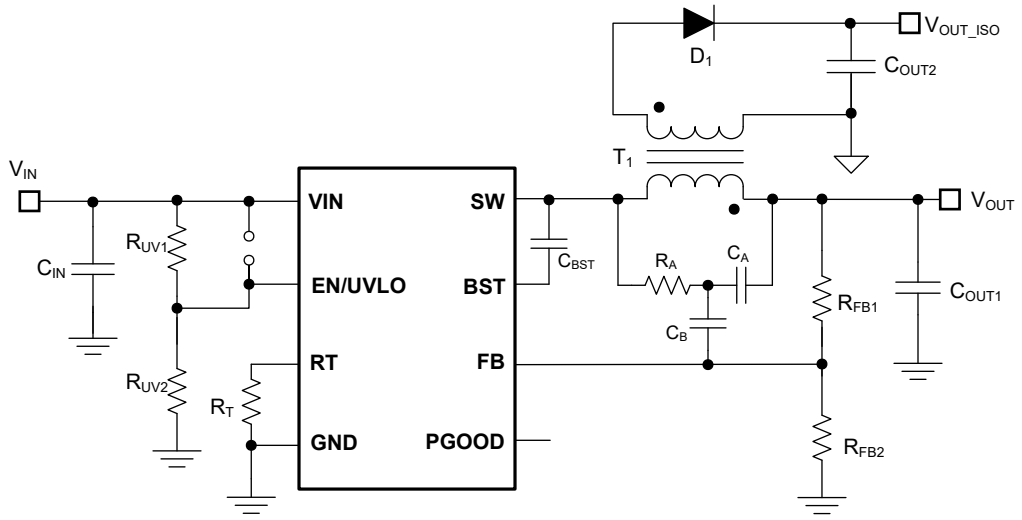


Figure 1-1. LMR71915EVM-FLBK Fly-Buck™ Converter Simplified Schematic

Table 1-2. Electrical Performance Characteristics

PARAMETER	TEST CONDITION		MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS						
Input voltage range, V_{IN}			34		115	V
Input voltage turn-on, V_{IN_ON}	Adjustable using EN/UVLO divider resistors			33.7		V
Input voltage turn-off, V_{IN_OFF}				31.4		V
Input current, operating with no load, I_{IN_NL}	I_{OUT} = I_{OUT_ISO}= 0A	V_{IN} = 48V		15.6		mA
		V_{IN} = 80V		15.7		mA
Input current, disabled, I_{IN_OFF}, excluding the external UVLO resistor leak current	V_{EN} = 0V, removing R5 and R7	V_{IN} = 48V		0.6		µA
		V_{IN} = 60V		0.7		µA
		V_{IN} = 80V		5.7		µA
OUTPUT CHACTERISTICS						
Primary output voltage, V_{OUT}			12.13	12.25	12.37	V
Isolated output voltage, V_{OUT_ISO}	I_{OUT_ISO} = 25mA to 625mA		11.0	12.0	13.0	V
Max load current on each output, I_{OUT}, I_{OUT_ISO}	V_{IN} = 36V				0.625	A
	V_{IN} = 48V				0.625	A
	V_{IN} = 80V				0.625	A
Soft-start time, t_{SS}	Internally Fixed			3		ms
SYSTEM CHARACTERISTICS						
Switching frequency	V_{IN} = 48V, I_{OUT} = I_{OUT_ISO} = 0.625A			500		kHz
Peak efficiency	V_{IN} = 36V, I_{OUT} = 0.625A, I_{OUT_ISO} = 0.05A to 0.30A			90		%
Half-load efficiency, η_{HALF}	I_{OUT} = I_{OUT_ISO} = 0.32A	V_{IN} = 36V		88		%
		V_{IN} = 48V		87		%
		V_{IN} = 80V		84		%
Full load efficiency, η_{FULL}	I_{OUT} = I_{OUT_ISO} = 0.625A	V_{IN} = 36V		83		%
		V_{IN} = 48V		84		%
		V_{IN} = 80V		82		%
Isolation rating	RMS voltage				1500	V
LMR71915 junction temperature, T_J			-40		150	°C

1.4 Device Information

The factory default settings of the EVM allow the operation with an input voltage range from 36V to 115V. The EVM can deliver a regulated 12.25V ±1% output, with 0.625A at 500kHz switching frequency, and an additional 12V floating output also capable of 0.625A. By opening the output voltage setting jumper J3, the user can conveniently change the output voltages to 5V, also with the load up to 0.625A on each of the two outputs.

The EVM is set up with type III ripple injection to minimize the output voltage ripple. The EVM also has built-in options to use type I or type II ripple injection. When changing to type I or type II ripple injection, please remove R4, C3, C5, C13, C14 and C15, but install C11 and C12 along with a proper resistor on R3. For type II ripple induction, C17 must also be installed. For selections of these components, see the *LMR719xx 1.5A, 0.75A, 115V, Step-Down Converter With Fly-Buck™ Converter Capability* data sheet data sheet for more information.

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 General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines* for the important notice on safety concerns when handling the EVM.

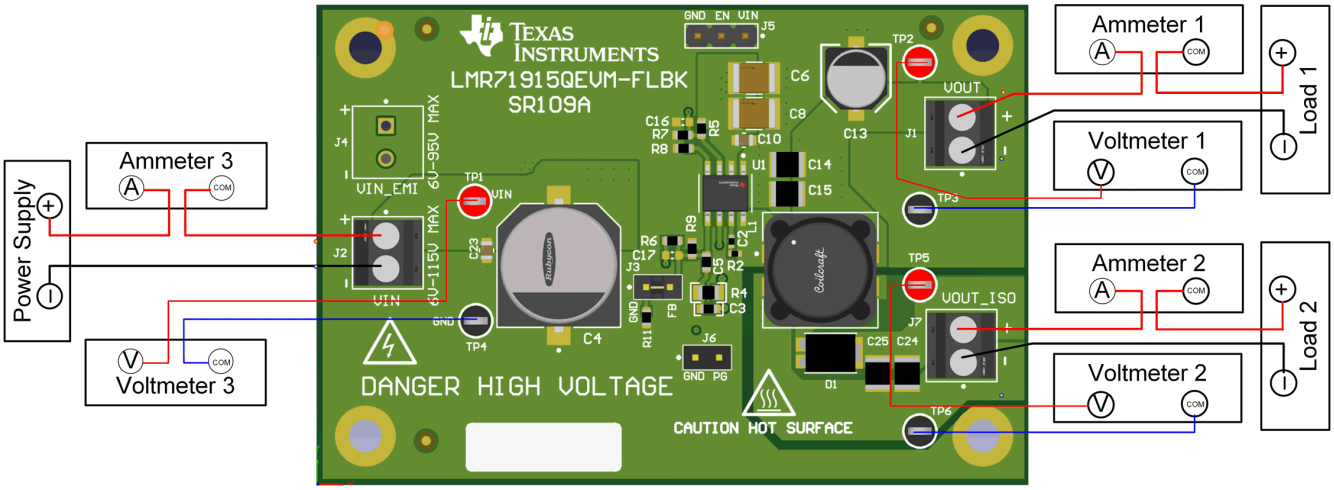


Figure 2-1. EVM Test Setup

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

- **Input Supply:** The input DC voltage source capable of at least 0-120V and 1A.
- **Load 1 and Load 2:** Resistor loads are preferred, one for the primary output, the other for the isolated output. When using electronic loads (E-loads), the loads must be in constant-resistance (CR) or constant-current (CC) mode, capable of 0 Adc to 1 Adc up to 15V. For a no-load input current measurement, disconnect the electronic load as the load can draw a small residual current.
- **Multimeters:**
  - **Voltmeter 1:** Primary output voltage V_{OUT} across TP2 and TP3. Set the voltmeter to an input impedance of 100MΩ.
  - **Voltmeter 2:** Isolated output voltage V_{OUT_ISO} across TP5 and TP6. Set the voltmeter to an input impedance of 100MΩ.
  - **Voltmeter 3:** Input voltage across TP1 and TP4. Set the voltmeter to an input impedance of 100MΩ.
    - For Iq measurement under light load or shutdown mode, disconnect Voltmeter 3 because Voltmeter 3 can draw a small residual current that can affect the Iq reading accuracy by Ammeter 3. Also remember to remove R7 to eliminate the leak path through the UVLO resistor divider.
  - **Ammeter 1:** Primary output current I_{OUT}. Set the ammeter to 1-second aperture time.
  - **Ammeter 2:** Isolated output current I_{OUT_ISO}. Set the ammeter to 1-second aperture time.
  - **Ammeter 3:** Input current I_{IN}. Set the ammeter to 1-second aperture time.
- **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. 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

The following table lists the header information of the EVM.

Table 2-1. Header Information

HEADER	SIGNAL	DESCRIPTION
J1-1	VOUT	Primary output voltage port
J1-2	GND	Primary output voltage return port, also the DC/DC stage primary reference ground
J2-1	VIN	Voltage source input port
J2-2	GND	Voltage source input return, also the DC/DC stage primary reference ground
J3	FB	Output voltage setting header. Default close for 12V output, and optional open for 5V output.
J4-1	VINEMI	Not installed. Optional EMI filter input port. 95V maximum rating.
J4-2	VINEMI return	Not installed. Optional EMI filter input return.
J5-1	VIN	Input voltage to the on-board UVLO resistor divider branch.
J5-2	UVLO	Optional Enable and UVLO control signal. Closing J5-1 and J5-2 bypasses on-board UVLO threshold circuit. Closing J5-2 and J5-3 disables the EVM.
J5-3	GND	Primary circuit reference ground.
J6-1	PG	Power-Good signal, pulled up by VOUT through an on-board 100k resistor.
J6-2	GND	Primary circuit reference ground.
J7-1	VOUT_ISO	Isolated output voltage port
J7-2	GND_ISO	Isolated output 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	Fly-Buck converter DC/DC stage input voltage
TP2	VOUT	Primary side output voltage
TP3	GND	Fly-Buck converter DC/DC stage input ground reference
TP4	GND	Primary side output ground reference
TP5	VOUT-ISO	Isolated output voltage
TP6	ISO-GND	Isolated output ground reference

2.4 Assembly Instructions

See *Section General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines* 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 100mA maximum. Verify the input source is initially set to 0V and connected to the (+) and (–) connection points of J2, as shown in Figure 2-1. TI recommends an additional input bulk capacitor to provide damping if long input lines are used.
- Connect Voltmeter 3 at TP1 and TP4 to measure the input voltage.
- Connect Ammeter 3 to measure the input current and set to at least 1-second aperture time.

Output Connections

- Connect Load 1, either a resistor load (preferred) or an E-load to (+) and (–) connection points of J1 as shown in Figure 2-1. Set the load to CR or CC mode at 0A before applying input voltage.
- Connect Load 2, either a resistor load (preferred) or an E-load to (+) and (–) connection points of J7 as shown in Figure 2-1. Set the load to CR or CC mode at 0A before applying input voltage

- Connect Voltmeter 1 at TP2 and TP3 to measure the primary output voltage V_{OUT}.
- Connect Voltmeter 2 at TP5 and TP6 to measure the isolated output voltage V_{OUT_ISO}
- Connect Ammeter 1 to measure the primary output current I_{OUT}.
- Connect Ammeter 2 to measure the isolated output current I_{OUT_ISO}

Test Procedure

- Set up the EVM as described above.
- Set the load to CR or CC mode to sink 10mA.
- Increase the input source from 0V to 36V; use Voltmeter 1 to measure the input voltage.
- Increase the current limit of the input supply to 1A.
- Use Voltmeter 1 to measure V_{OUT}, and vary Load 1 from 10mA to 625mA DC; V_{OUT} must remain within the load regulation specification.
- Use Voltmeter 2 to measure V_{OUT_ISO}, and vary Load 2 from 20mA to 625mA DC; V_{OUT_ISO} must remain within the load regulation specification.
- Set both Load 1 and Load 2 to sink 320mA each, which are roughly 50% rated load, and vary the input source voltage from 36V to 115V; V_{OUT} and V_{OUT_ISO} must remain within the line regulation specification.
- Use the oscilloscope to probe different signals of interest. Be careful of the probe ground reference, especially when probing the isolated voltage rail.
- Decrease both Load 1 and Load 2 to 10mA. Decrease the input source voltage to 0V.
- Shut down both the input source and loads, and then the voltmeters and ammeters.

General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

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

Save all warnings and instructions for future reference.

WARNING

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

1. Work Area Safety:
   a. Keep work area clean and orderly.
   b. Qualified observers must be present anytime circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   e. Use stable and non-conductive work surface.

f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.

2. Electrical Safety:
   a. As a precautionary measure, a good engineering practice is to assume that the entire EVM can have fully accessible and active high voltages.
   b. De-energize the TI HV EVM and all the inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   c. 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.
   d. Once EVM readiness is complete, energize the EVM as intended.

WARNING

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

3. Personal Safety
   a. Wear personal protective equipment e.g. latex gloves 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.

3 Implementation Results

3.1 Performance Data and Results

Figure 3-1 through Figure 3-6 present typical performance curves for the LMR71915EVM-FLBK. 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

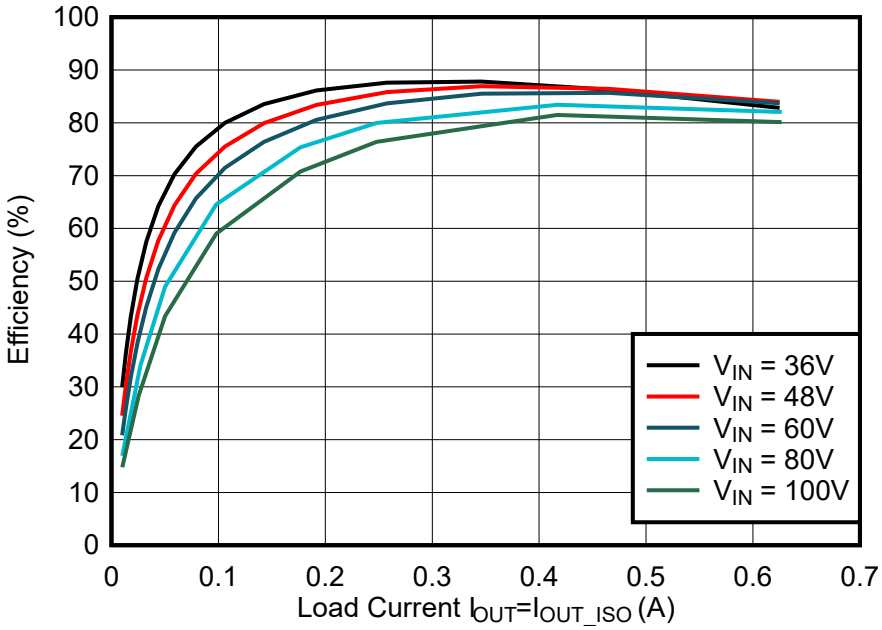


Figure 3-1. EVM Efficiency vs Load and Input Voltage

3.1.2 Output Voltage Regulation

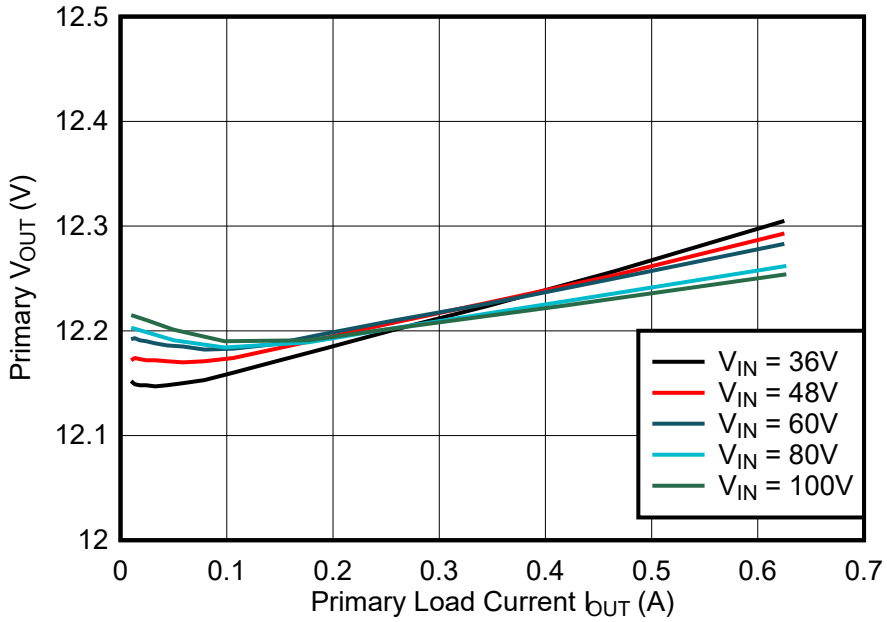


Figure 3-2. EVM Primary Output Voltage Regulation vs Load and Input Voltage

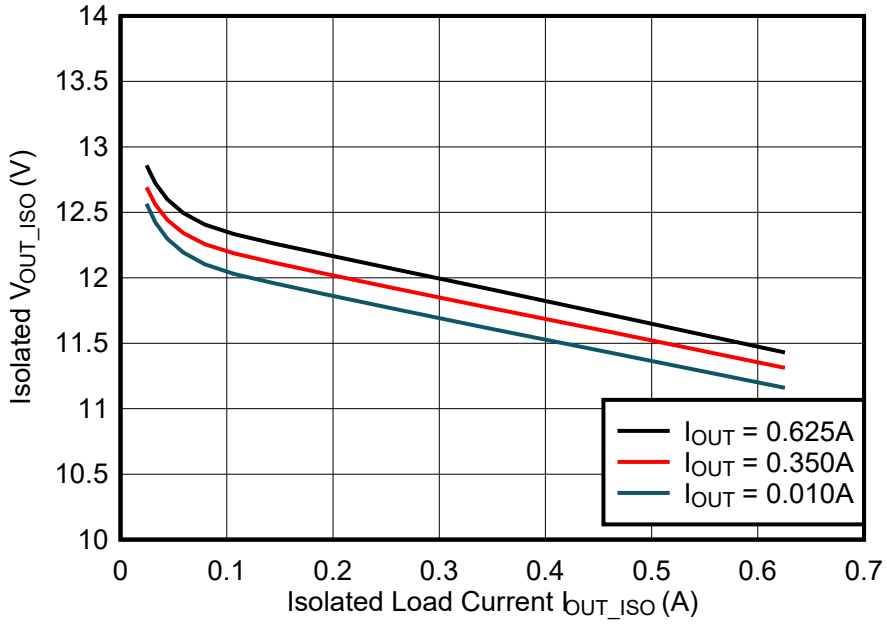


Figure 3-3. EVM Isolated Output Voltage Regulation vs Load Current under V_{IN} = 48V

3.1.3 Operating Waveforms

3.1.3.1 Start-Up

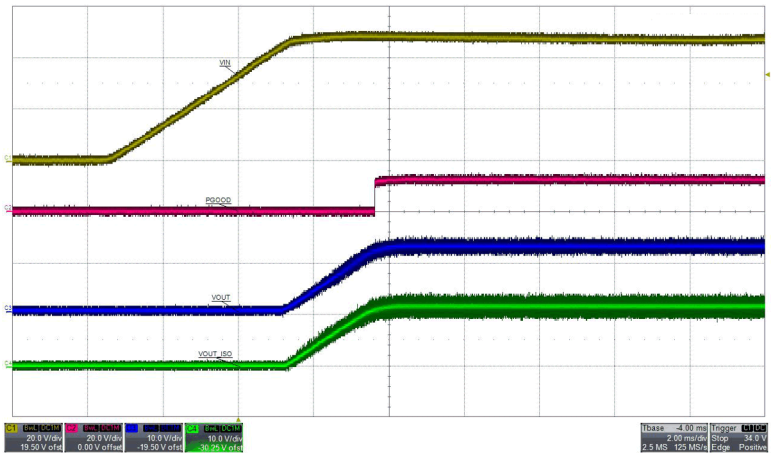


Figure 3-4. Typical Power-Up Under Full Load: V_{IN}= 48V, I_{OUT} = I_{OUT_ISO} = 0.625A

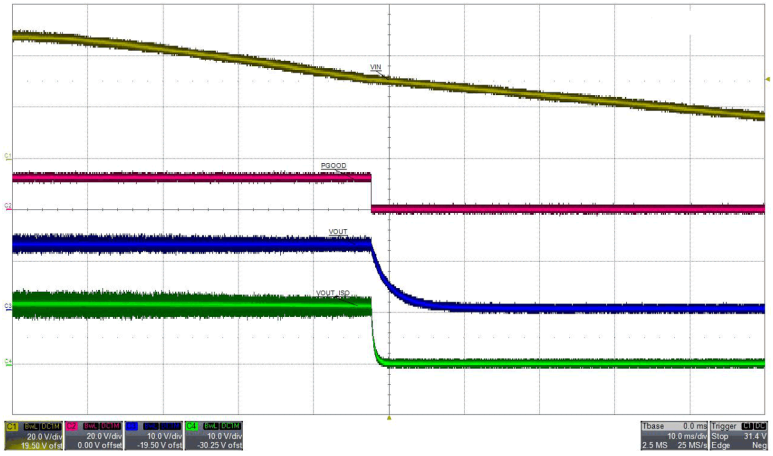


Figure 3-5. Typical Power-Down Under Full Load: V_{IN}= 48V to 0V, I_{OUT} = I_{OUT_ISO} = 0.625A

3.1.3.2 Switching

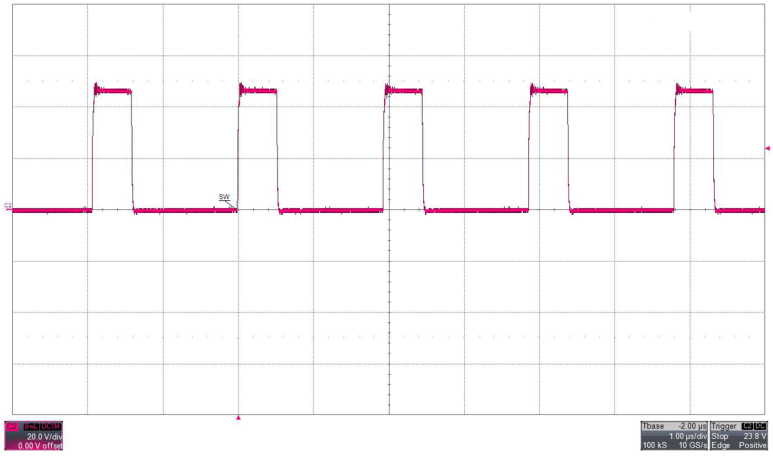


Figure 3-6. Typical Switching Waveform: V_{IN} = 48V, I_{OUT} = I_{OUT_ISO} = 0.625A

3.2 Thermal Performance

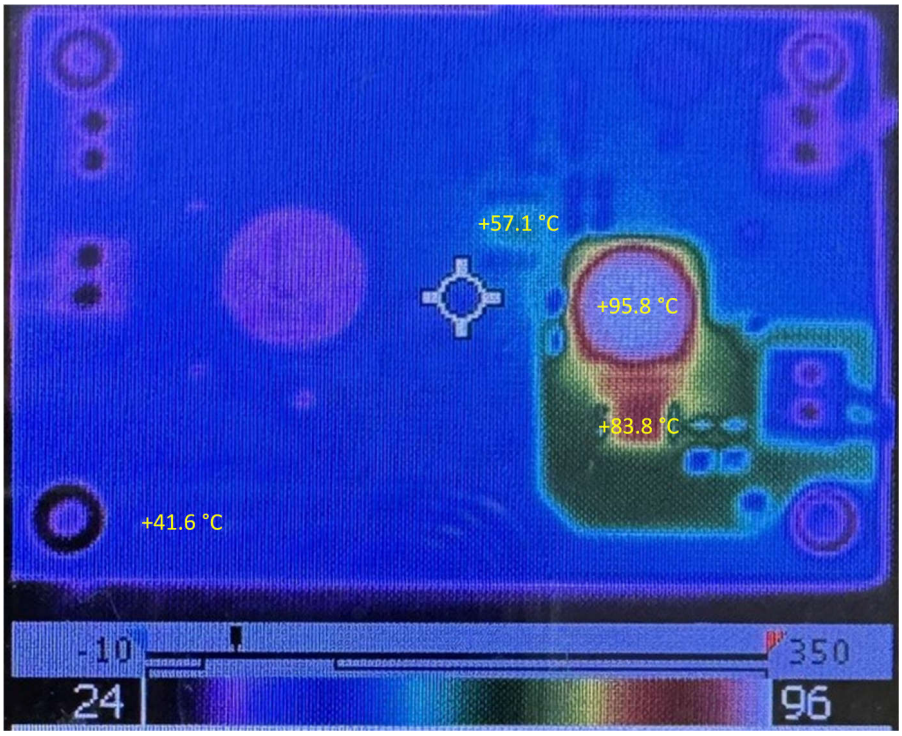


Figure 3-7. EVM Thermal Image, V_{IN} = 48V, I_{OUT} = I_{OUT_ISO} = 0.625A. T_A = 25°C, No Airflow

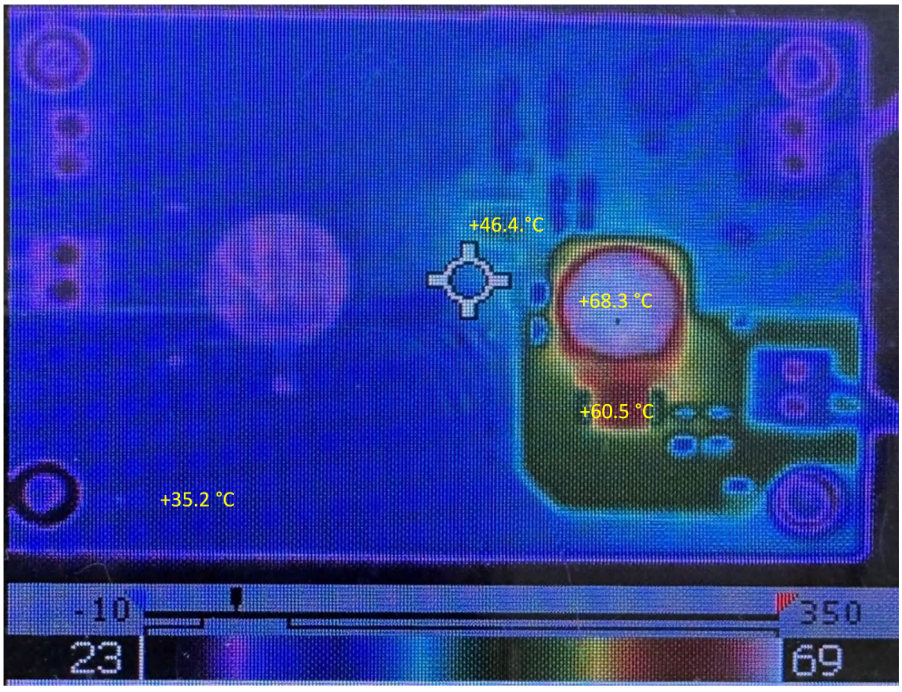


Figure 3-8. EVM Thermal Image, V_{IN} = 48V, I_{OUT} = I_{OUT_ISO} = 0.500A. T_A = 25°C, No Airflow

4 Hardware Design Files

4.1 Schematic

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

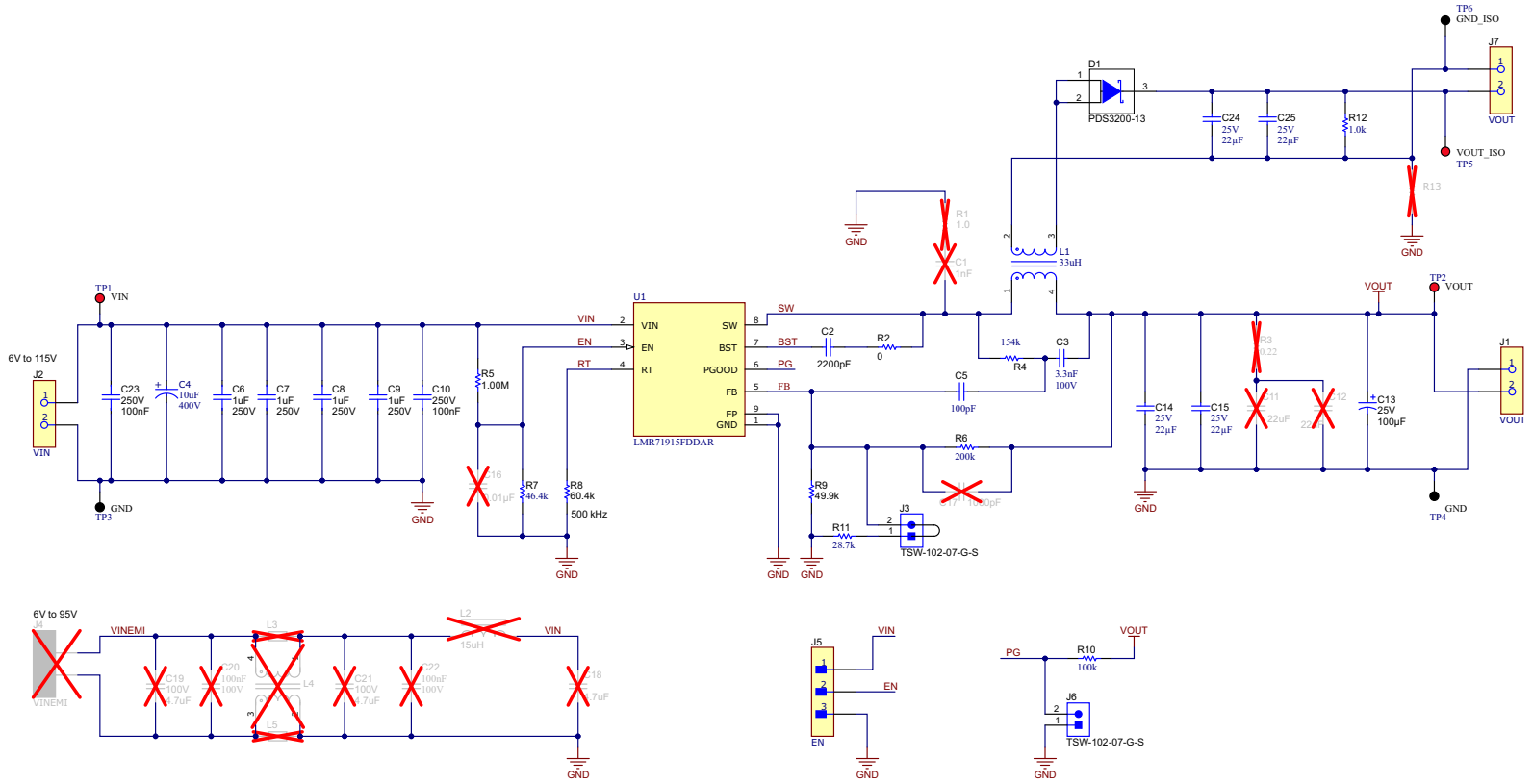


Figure 4-1. LMR71915EVM-FLBK Schematic

4.2 PCB Layout

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

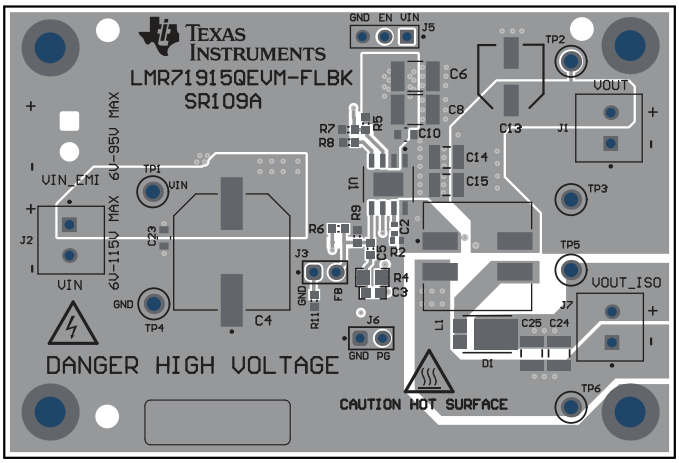


Figure 4-2. Top Layer Silkscreen (Top View)

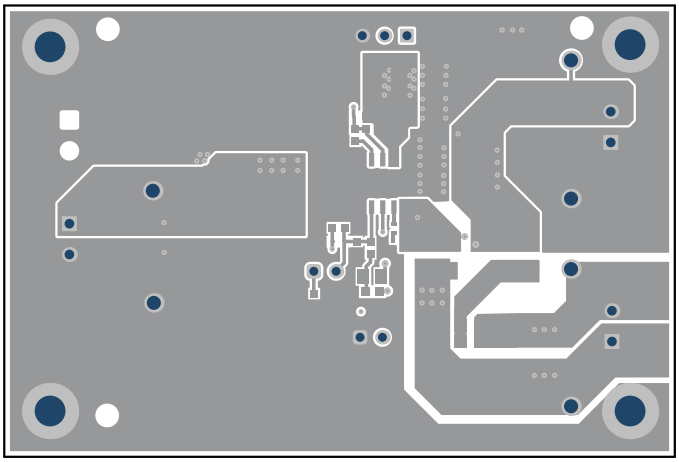


Figure 4-3. Top Layer Layout (Top View)

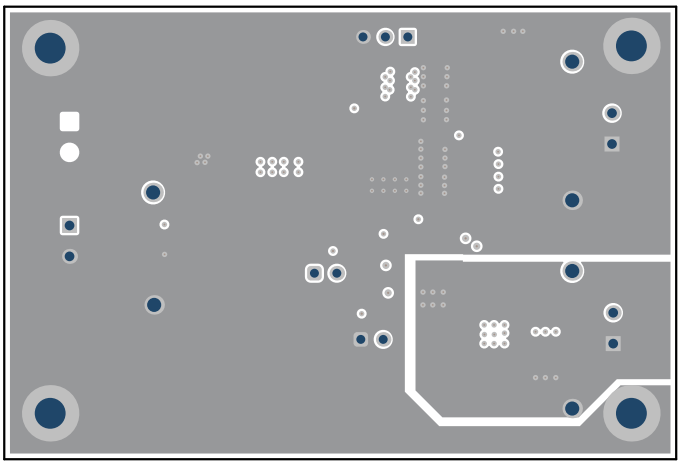


Figure 4-4. Mid Layer 1 Layout (Top View)

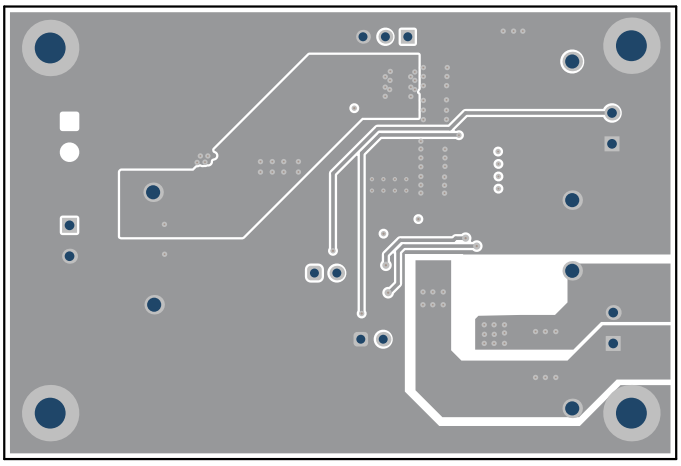


Figure 4-5. Mid Layer 2 Layout (Top View)

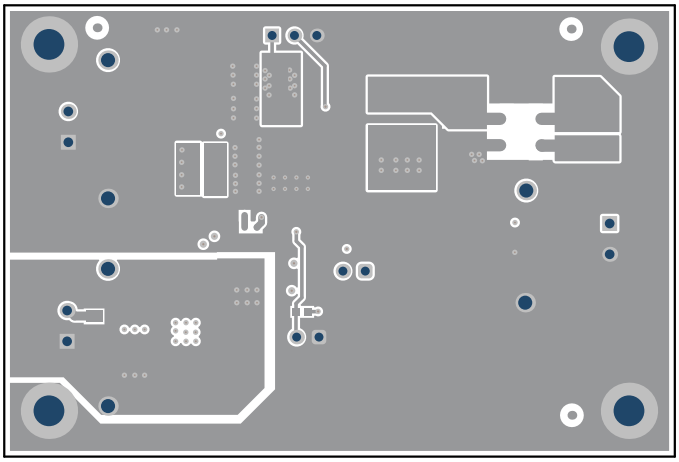


Figure 4-6. Bottom Layer Layout (Bottom View)

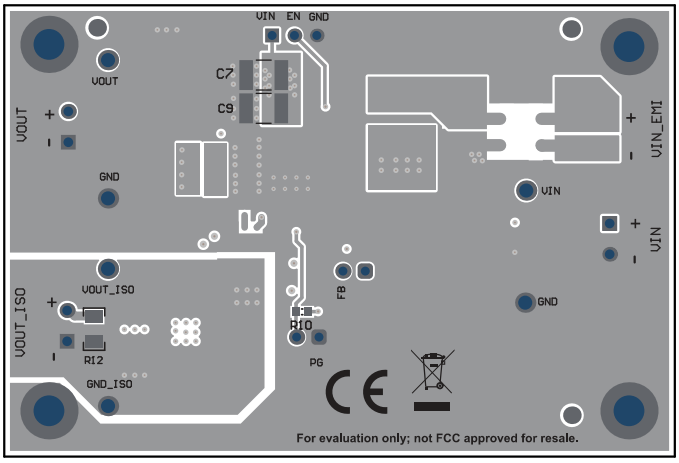


Figure 4-7. Bottom Layer Silkscreen (Bottom View)

4.3 Bill of Materials (BOM)

The following table lists the LMR71915EVM-FLBK bill of materials (BOM).

Table 4-1. Bill of Materials

DESIGNATOR	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
C2	1	CAP, CERM, 2200pF,50V, +/– 10%, X7R, AEC-Q2000 Grade 1, 0402	GCM155R71H222KA37D	MuRata
C3	1	CAP, CERM, 3300pF, 100V, +/– 10%, X7R, AEC-Q200 Grade 1, 0603	GCM188R72A332KA37D	MuRata
C4	1	Cap Aluminum 10µF 400V 20% (12.5 X 13.5mm) Solder Pin Cylindrical 92mA 5000 hr 105°C Bulk	400SGV10M12.5X13.5	Rubycon
C5	1	CAP, CERM, 100pF, 50V, +/– 5%, C0G/NP0, AEC-Q200 Grade 0, 0603	CGA3E2NP01H101J080AA	TDK
C6, C7, C8, C9	4	1µF ±10% 250V Ceramic Capacitor X7R 1812 (4532 Metric)	1812Y2500105KXTWS2	Knowles Syfer
C10, C23	2	0.1µF ±10% 250V Ceramic Capacitor X7T 0805 (2012 Metric)	C2012X7T2E104K125AE	TDK
C13	1	CAP, AL, 100µF, 25V, +/– 20%, SMD	UWT1E101MCL1GS	Nichicon
C14, C15, C24, C25	4	CAP, CERM, 22µF, 25V,+/– 10%, X7R, AEC-Q200 Grade 1, 1210	TMK325B7226KMHP	Taiyo Yuden
D1	1	Diode, Schottky, 200V, 3A, PowerDI5	PDS3200-13	Diodes Inc.
L1	1	Coupled Inductor 33µH 20% 100kHz 12x12x6mm SMT	ZF3233-AE	Coilcraft
		Coupled inductor, 33µH, 3.9A, 0.087ohm, SMD	744873330	Wurth Elektronik
R2	1	RES, 0, 5%, 0.063W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale
R4	1	RES, 154k, 1%, 0.125W, AEC-Q200 Grade 0, 0805	ERJ-6ENF1543V	Panasonic
R5	1	RES, 1.00M, 1%, 0.1W, 0603	RC0603FR-071ML	Yageo
R6	1	RES, 200k, 1%, 0.1W, AEC-Q200 Grade 0, 0603	CRCW0603200KFKEA	Vishay-Dale
R7	1	RES, 46.4k, 1%, 0.1W, 0603	RC0603FR-0746K4L	Yageo
R8	1	RES, 60.4k, 1%, 0.1W, 0603	RC0603FR-0760K4L	Yageo
R9	1	RES, 49.9k, 0.1%, 0.1W, 0603	RG1608P-4992-B-T5	Susumu Co Ltd
R10	1	RES, 100k, 1%, 0.1W, AEC-Q200 Grade 0, 0603	CRCW0603100KFKEA	Vishay-Dale
R11	1	RES, 28.7k, 1%, 0.1W, 0603	RES, 28.7k, 1%, 0.1W, 0603	Yageo
R12	1	RES, 1.0k, 5%, 0.25W, AEC-Q200 Grade 0, 1206	CRCW12061K00JNEA	Vishay-Dale
U1	1	1.5A, 115V, Step-down converter with Fly-Buck converter capability, HSOIC-8	LMR71915FDDAR	Texas Instruments

5 Compliance Information

5.1 Compliance and Certifications

LMR71915EVM-FLBK EU Declaration of Conformity (DoC) certificate for Restricting the Use of Hazardous Substances (RoHS)

6 Additional Information

6.1 Trademarks

Fly-Buck™ is a trademark of Texas Instruments.
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 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 2 4 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.

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