LM5161PWPFBKEVM (Fly-Buck™) Evaluation Module

User's Guide

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LM5161 Fly-Buck™ EVM User's Guide

1 Introduction

The LM5161PWPFBKEVM evaluation module helps designers evaluate the operation and performance of the LM5161 in the Fly-Buck (isolated buck) configuration. The Fly-Buck topology is derived from the synchronous buck topology by replacing the buck inductor with a transformer (coupled inductor) to produce both primary (non-isolated) and secondary (isolated) outputs. This user's guide highlights the specifications, setup instructions, complete application schematic, bill of materials (BOM), and typical performance curves. The LM5161 device name is used generically throughout this document and represents both the LM5161 and the LM5161-Q1, unless stated otherwise.

2 EVM Description and Performance Specifications

The LM5161PWPFBKEVM is designed to operate from a 48 V nominal bus with the input voltage varying from 36 V to 72 V. It is capable of supplying 12 V at the secondary isolated side with the load rated up to 800 mA. The nominal switching frequency is set at 300 kHz. The EVM is designed to demonstrate a small Fly-Buck solution size with the HTSSOP-14 package (LM5161) for a 10-W isolated bias power supply applications.

Table 1. Default Board Specification

INPUT	FREQUENCY	V_{OUT}	V_{OUTISO}	I_{OUTISO}
VIN = 36 V–72 V	300 kHz	12.7 V	12 V	0–800 mA

3 Test Setup and Operation

This section describes the connectors and test-points on the EVM as well as how to correctly connect, setup and use the LM5161PWPFBKEVM with the LM5161 IC for isolated bias power supply applications.

3.1 Recommended Test Setup

3.1.1 Input/Output Connector Description

J1 – Output is the **Isolated** output voltage terminal of the EVM. The terminal block 12VISO (+) with the isolated ground (-) allows the user to attach the EVM to an isolated load.

J3 – Output is the primary **Non-Isolated** regulated output voltage terminal of the EVM. The terminal block 12VPRI (+) and ground (-) allows the user to attach the EVM to a non-isolated load.

J2 – Input is the power input terminal of the EVM. The terminal block provides input VIN(+) and the ground (-) allows the user to attach the EVM to a power supply, nominally a 48-V supply.

TP1 – (SW) allows the user to connect a scope probe to measure the primary side switching node of the converter.

J4– (GND) allows the user to connect the ground of the scope probe for the primary side measurements.

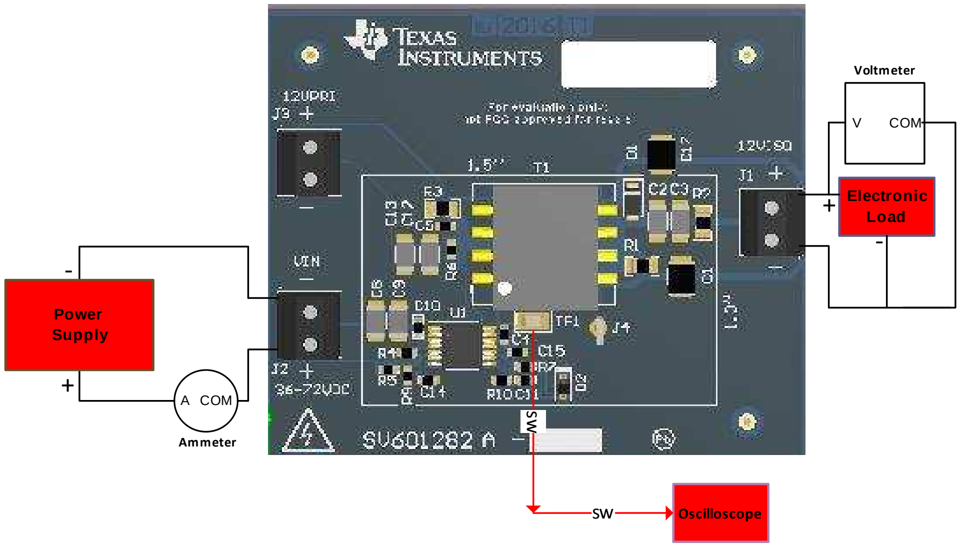


Figure 1. EVM Test Setup

3.2 Operation

To power up the Fly-Buck EVM, gradually increase the input voltage, applied across **J2**. The load on the secondary output (**J1**), with primary output (**J3**) unloaded, should not exceed 800 mA, which corresponds to a 15-Ω resistive load. If the primary is loaded, the total load on the two outputs should not exceed 800 mA. The transformer **T1** used in the EVM is optimized for a 10 W isolated bias supply application. The transformer **T1** care has been carefully selected in order to ensure that it can tolerate any short circuit condition on the isolated secondary side of the EVM, without getting saturated.

When the input voltage exceeds approximately 36 V, the primary and secondary outputs (**J3** and **J1**) power up to approximately 12.7 V and 12 V respectively.

The frequency of operation is set by using the R4 resistor (R_{ON}) in Equation 1 :

$$F_{SW} = \frac{V_{OUT}}{1.008 \text{ x } 10^{-10} \text{ x } R_4} \tag{1}$$

The primary output voltage V_{OUT} can be set at 12.7 V, with the feedback divider resistors R7 ($R_{FB(Top)}$) , R10 ($R_{FB(Bottom)}$) and the V_{REF} = 2 V, using the Equation 2 :

$$V_{OUT} = \left(1 + \frac{R_{FB(Top)}}{R_{FB(Bottom)}}\right) \times V_{REF} = \left(1 + \frac{R7}{R10}\right) \times 2\text{V} \tag{2}$$

The secondary isolated output (V_{OUTISO}) is related to the primary output V_{OUT} by the transformer turns ratio and the forward voltage drop of the secondary side diode D1, (V_{FD1}) :

$$V_{OUT} = \frac{V_{OUTISO} + V_{FD1}}{\frac{N_2}{N_1}} = \frac{V_{OUTISO} + 0.7\text{V}}{1} = 12.7\text{V} \tag{3}$$

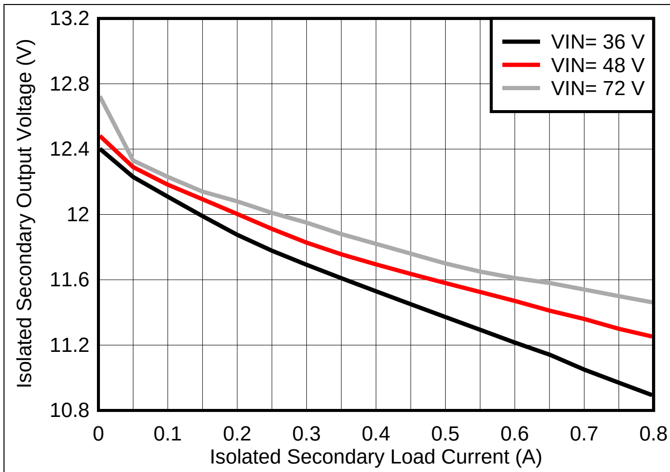
where $N_2 : N_1$ is the transformer turns ratio ($N_{SEC} : N_{PRI}$) and V_{FD1} is the forward voltage drop of the secondary rectifier diode. The Equation 3 above is simplified and does not account for the DCR voltage and the leakage inductances voltage drops across the primary and the secondary windings of the transformer, which have effect on the secondary (isolated) side regulation.

The secondary-side rectifier diode must block the maximum input voltage reflected at the secondary-side. The minimum diode reverse voltage V_{RD1} rating is given in Equation 4.

$$V_{RD1} = V_{IN(max)} \times \frac{N_2}{N_1} + V_{OUTISO} = 72V \times 1 + 12V = 84V \quad (4)$$

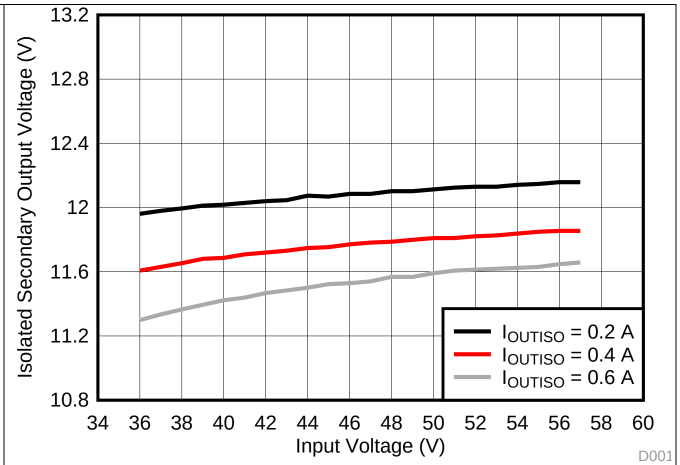
A diode with a 100-V reverse voltage rating is selected here. If the input voltage (V_{IN}) has transients above the normal operating maximum input voltage of 72 V, then the worst-case transient input voltage value must be used in Equation 4 when selecting the secondary-side rectifier diode for the LM5161 Fly-Buck EVM.

4 Typical Performance Curves



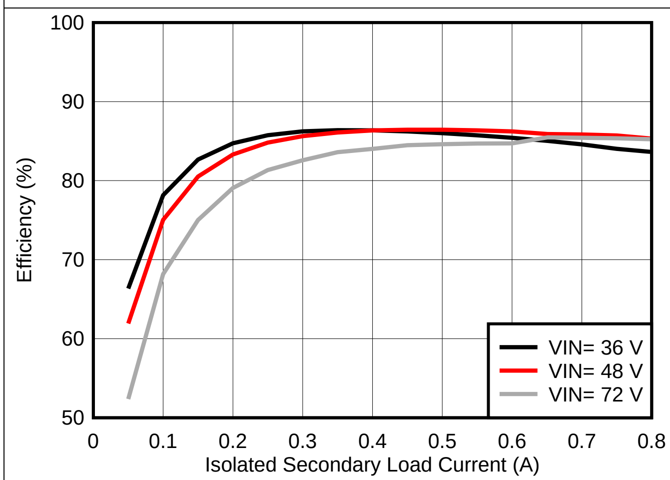
Primary Side
Load = 0 A

Figure 2. Secondary Side (V_{OUTISO}) Load Regulation



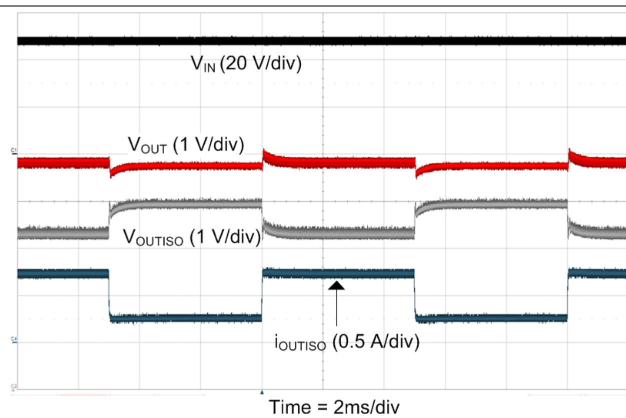
Primary Side
Load = 0 A

Figure 3. Secondary Side (V_{OUTISO}) Line Regulation



Primary Side
Load = 0 A

Figure 4. Efficiency vs I_{OUTISO} with Default Board Configuration



Primary Side
Load = 0 A

Figure 5. Secondary Isolated Output Load Transient at V_{IN} = 48 V and I_{OUTISO} = 250 mA to 750 mA

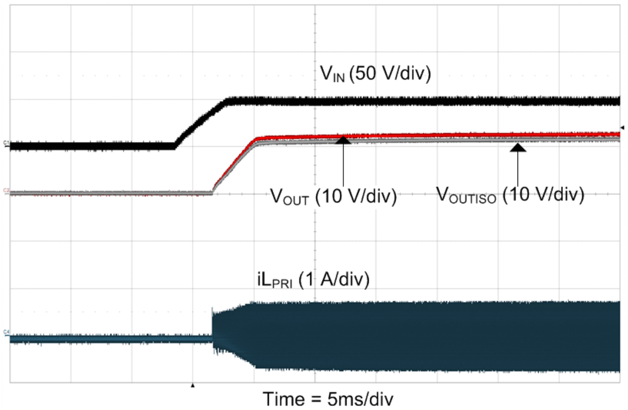


Figure 6. Startup Waveforms at I_{OUTISO} = 500 mA and I_{PRI} = 0 A

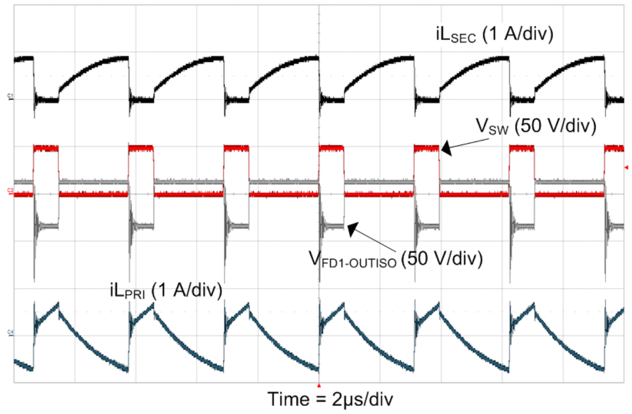


Figure 7. Steady State waveforms at V_{IN} = 48 V and I_{OUTISO} = 500 mA

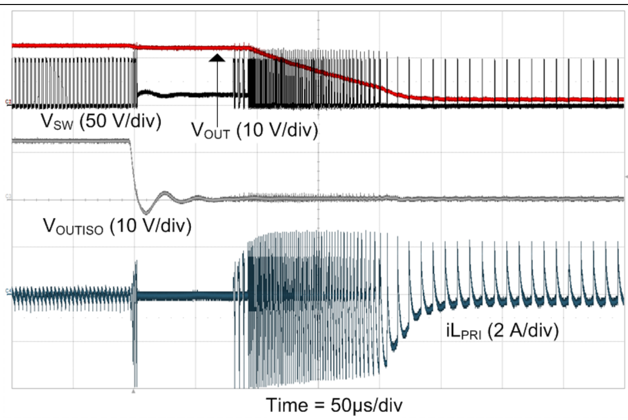


Figure 8. Secondary-side Short applied when I_{OUTISO} = 0 A and I_{PRI} = 0 A

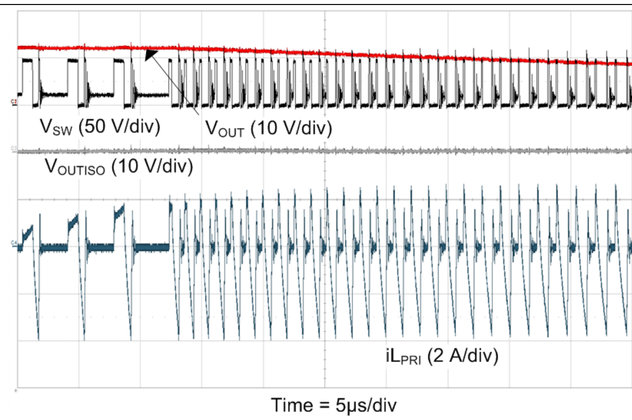


Figure 9. Secondary-Side Short Applied when I_{OUTISO} = 0 A and I_{PRI} = 0 A (Zoomed After Short is Applied)

5 LM5161 Fly-Buck EVM Schematic

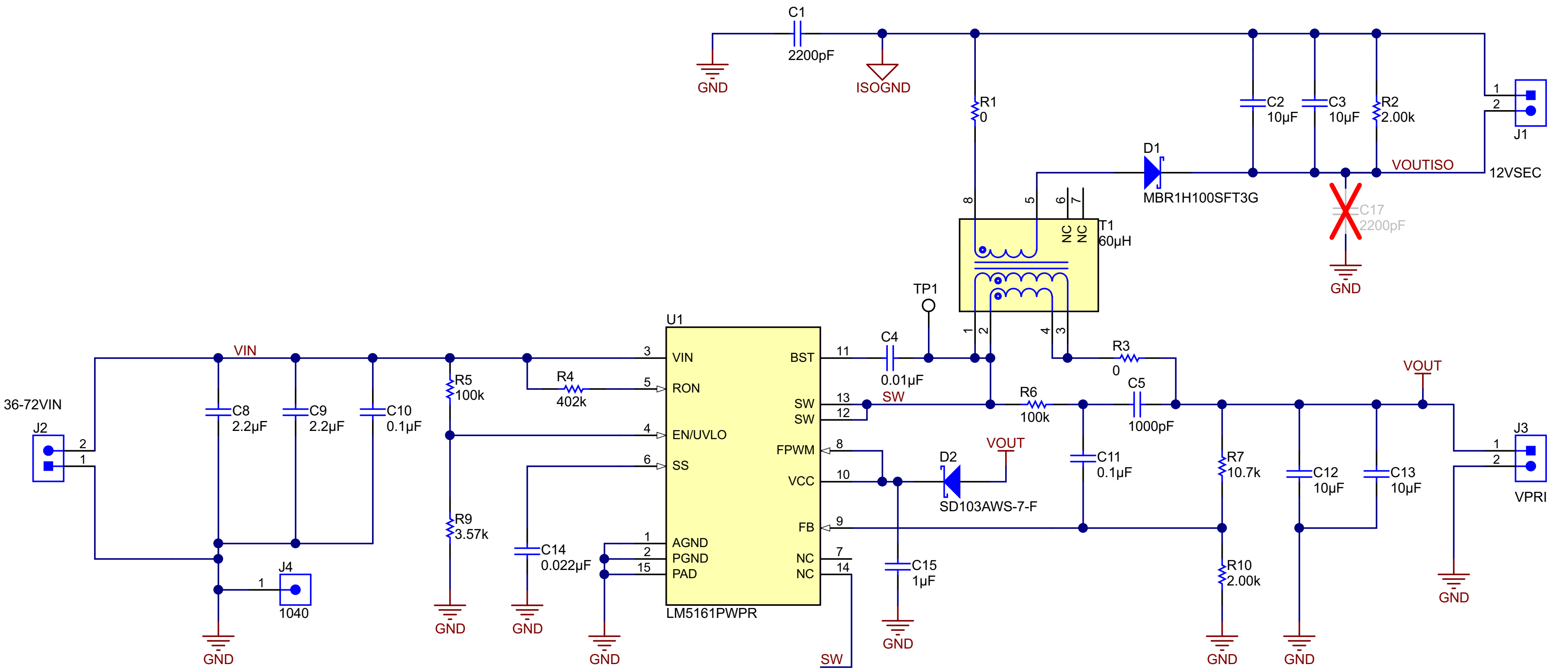


Figure 10. Fly-Buck EVM Schematic with the LM5161 IC

Figure 10 shows the Fly-Buck configuration using the LM5161 with VCC externally powered from V_{OUT} with diode D2 for improved efficiency requirements. Table 2 provides the complete LM5161PWPFBKEVM Bill of Materials.

6 LM5161 Fly-Buck EVM Bill of Materials

Table 2. LM5161PWPFBKEVM Bill of Materials for 300 kHz Configuration

COUNT	REF DES	DESCRIPTION	SIZE	MFR	PART NUMBER
4	C2, C3, C12, C13	CAP, CERM, 10 µF, 25 V, ± 20%, X7R	1206	TDK	C3216X7R1E106M160AE
1	C1	CAP, CERM, 2200 pF, 2000 V, ± 10%, X7R	1210	Johanson Technology	202S41W222KV4E
1	C4	CAP, CERM, 0.01uF, 16 V, ± 10%, X7R	0603	MuRata	GRM188R71C103KA01D
		CAP, CERM, 0.01uF, 16 V, ± 10%, X7R (Alternative Part)		Würth Elektronik	885012206040
1	C5	CAP, CERM, 1000 pF, 100 V, ± 10%, X7R	0603	MuRata	GRM188R72A102KA01D
2	C8, C9	CAP, CERM, 2.2 µF, 100 V, ± 10%, X7R	1206	MuRata	GRM31CR72A225KA73L
1	C10	CAP, CERM, 0.1 µF, 100 V, ± 10%, X7R	0603	MuRata	GRM188R72A104KA35D
1	C11	CAP, CERM, 0.1 µF, 25 V, ± 5%, X7R	0603	AVX	06033C104JAT2A
		CAP, CERM 0.1 µF 25 V, ± 10%, X7R (Alternative Part)		Würth Elektronik	885012206071
1	C14	CAP, CERM, 0.022 µF, 50 V, ± 10%, X7R	0603	MuRata	GRM188R71H223KA01D
		CAP, CERM 0.022 µF, 50 V, ± 10%, X7R (Alternative Part)		Würth Elektronik	885012206091
1	C15	CAP, CERM, 1 µF, 25 V, ± 10%, X7R	0603	MuRata	GRM188R71E105KA12D
		CAP, CERM, 1 µF, 25 V, ± 10%, X7R (Alternative Part)		Würth Elektronik	885012206076
1	C17	CAP, CERM, 2200 pF, 2000 V, ± 10%, X7R	1210	Johanson Technology	202S41W222KV4E
1	D1	Diode, Schottky, 100 V, 1 A, SOD-123FL	SOD-123FL	ON Semi	MBR1H100SFT3G
1	D2	Diode, Schottky, 40 V, 0.35 A, SOD-323	SOD-323	Diodes Inc.	SD103AWS-7-F
3	J1, J2, J3	Terminal Block, 6A, 3.5mm Pitch, 2-Pos, TH	7.0 mm x 8.2 mm x 6.5 mm	On-Shore Technology	ED555/2DS
2	R1, R3	RES, 0 Ω, 5%, 0.125 W	0805	Vishay-Dale	CRCW08050000Z0EA
1	R2	RES, 2.00 k, 1%, 0.125 W	0805	Vishay-Dale	CRCW08052K00FKEA
1	R4	RES, 402 k, 1%, 0.1 W, 0603	0603	Vishay-Dale	CRCW0603402KFKEA
2	R5, R6	RES, 100 k, 1%, 0.1 W, 0603	0603	Vishay-Dale	CRCW0603100KFKEA
1	R7	RES, 10.7 k, 1%, 0.1 W, 0603	0603	Vishay-Dale	CRCW060310K7FKEA
1	R9	RES, 3.57 k, 1%, 0.1 W, 0603	0603	Vishay-Dale	CRCW06033K57FKEA
1	R10	RES, 2.00 k , 1%, 0.1W, 0603	0603	Vishay-Dale	CRCW06032K00FKEA
1	T1	Transformer, 60 µH	SMT	Würth Elektronik	750315811
1	TP1	Test Point, Miniature	SMT	Keystone	5015
1	U1	Wide Input 65V, 1.5A Synchronous Step-Down DC-DC Converter	4.4 mm x 5 mm HTSSOP-14	Texas Instruments	LM5161PWPR

7 LM5161 Fly-Buck EVM PCB Layout

Figure 11 to Figure 14 below show the top and bottom layers of the LM5161PWPFBKVM. The LM5161PWPFBKEVM is a two layer board.

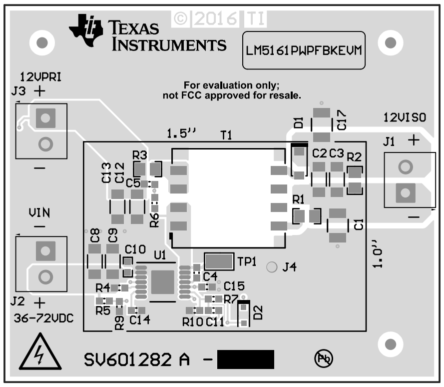


Figure 11. EVM Component View (Top)

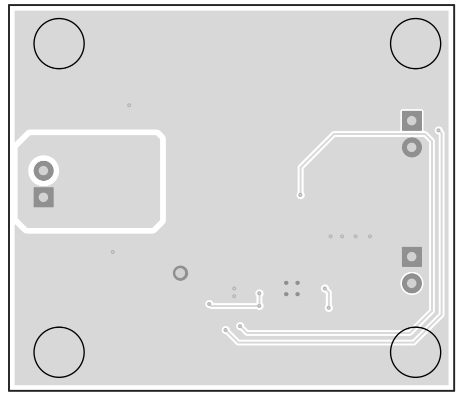


Figure 12. EVM Component View (Bottom)

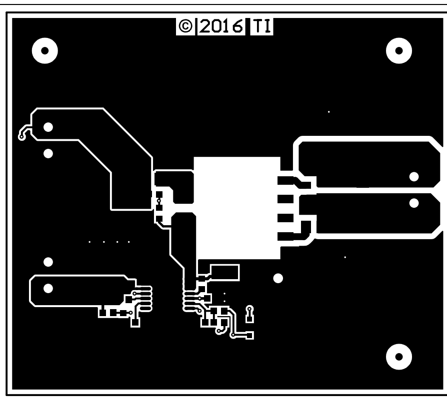


Figure 13. EVM Copper View (Top)

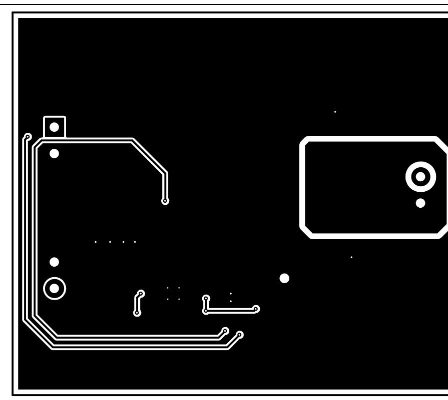


Figure 14. EVM Copper View (Bottom)

Revision History

Changes from Original (August 2016) to A Revision	Page
• Changed Orderable name to LM5161PWPR	9

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

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3 *Regulatory Notices:*

   3.1 *United States*

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

      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*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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。 http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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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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.

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