LM5161PWPBKEVM Buck Evaluation Module

User's Guide

Literature Number: SNVU504A
August 2016–Revised August 2016

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LM5161 Buck EVM User's Guide

1 Introduction

The LM5161 evaluation module (EVM) is designed to showcase the performance of the LM5161 synchronous buck DC/DC buck converter. The purpose of the user's guide is to highlight the specifications, setup instructions, complete application schematic, bill of materials (BOM), and typical performance curves of the EVM. The LM5161 is supported by WEBENCH® Designer and unencrypted PSpice simulation models. Furthermore, the reader can use the LM5161 Quick-start calculator to optimize component selection and examine estimated efficiency performance across wide line and load ranges. 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 LM5161 Buck evaluation board provides a fully functional buck regulator, employing the constant ON-time (COT) control scheme. This provides a 12 V output over an input voltage range of 15 V to 80 V with output current rated up to 1 A. The application schematic of the EVM has been set up to operate from a nominal 48-V input supply. The switching frequency is set to approximately 300 kHz. The board is designed to demonstrate a synchronous buck with small solution size for 12 W wide V_{IN} applications.

Table 1. LM5161 Buck EVM Specifications

ORDERABLE NAME	V_{IN}	V_{OUT}	I_{OUT}	EFFICIENCY
LM5161PWPBKEVM	15 V–80 V	12 V	0 A –1 A	94%

3 Test Setup and Operation

This section describes the connectors, the test points and the jumpers in the EVM.

3.1 Recommended Test Setup

3.1.1 Input/Output Connector Description

J1 – Input is the power input terminal for the converter. The terminal block provides an input V_{IN} (+) and ground (-) connection to allow the user to attach the EVM to a power supply.

J2 – Output is the regulated output voltage terminal for the converter. The terminal block provides a V_{OUT} (+) and ground (-) connection to allow the user to attach the EVM to a load.

J3 – (EN) allows the user to remotely shutdown/startup LM5161.

J4 – (V_{OUT} to V_{CC} connection) allows the user to check for the operation with and without the external V_{CC} connection (V_{CC} pin diode connected to V_{OUT})

JP1 – **MODE** pin allows the user to select between forced CCM (FPWM = 1) and DCM (FPWM = 0) operation. See Section 3.2 and Table 2 for more details.

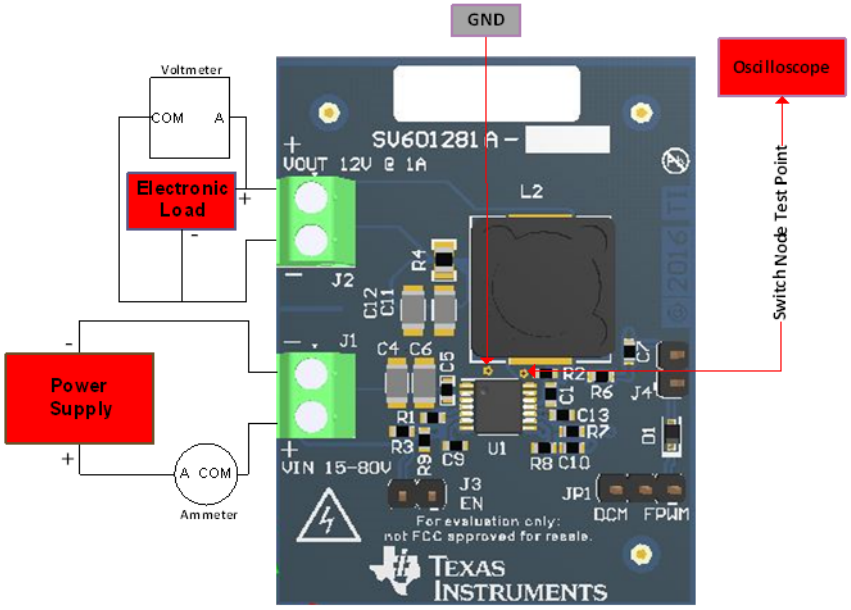


Figure 1. Buck EVM Setup

3.2 Operation

In order to maintain proper operation of the LM5161PWPBKEVM, the input voltage applied across J1 should be gradually increased. The load at the output (J2) should not exceed 1 A. The inductor L2 used in this board is optimized for small solution size. The saturation current rating (I_{SAT}) of the inductor should be higher than the LM5161 integrated high-side FET peak current-limit threshold of 1.9 A (max.).

The nominal switching frequency (in Hz) can be set using the R_{ON} (R1 in the EVM) resistor, as shown in Equation 1:

$$F_{SW} = \frac{V_{OUT}}{1.008 \times 10^{-10} \times R_{ON}} \text{ Hz} \quad (1)$$

The output voltage is set by using the feedback divider resistors R8 (R_{FB1}) and R7 (R_{FB2}) in the EVM by using Equation 2:

$$\frac{R_{FB2}}{R_{FB1}} = \frac{V_{OUT}}{V_{REF}} - 1 \quad (2)$$

The EN/UVLO resistors R9 (R_{UV1}) and R3 (R_{UV2}) in the EVM sets the input undervoltage lockout threshold and the EN/UVLO hysteresis according to Equation 3:

$$V_{IN(HYS)} = I_{UVLO(HYS)} \times R_{UV2} \quad (3)$$

and,

$$V_{IN,UVLO(rising)} = V_{UVLO(TH)} \left(1 + \frac{R_{UV2}}{R_{UV1}}\right) \quad (4)$$

where $I_{UVLO(HYS)}$ = 20 µA and $V_{UVLO(TH)}$ = 1.24 V.

Table 2 summarizes the LM5161 Buck EVM Jumper (JP1) settings that determine the desired modes of operation.

- **Forced continuous conduction mode (CCM) or FPWM**
- **Discontinuous conduction mode (DCM)**

When selecting the FPWM mode, the LM5161 needs an external feedback ripple injection circuit (Type 3) **or** the external ESR resistor (Type 1) on board, for normal operation. The correct values for the external ESR resistor (R4 in the EVM) in series with the output capacitors (C10, C11) or for the external ripple injection circuit (R6,C7 and C10), depending on which ripple injection scheme (Type 1 or Type 3) is used, are calculated based on the formulae mentioned in the LM5161 datasheet. See application note AN-1481 for more details for each ripple generation method.

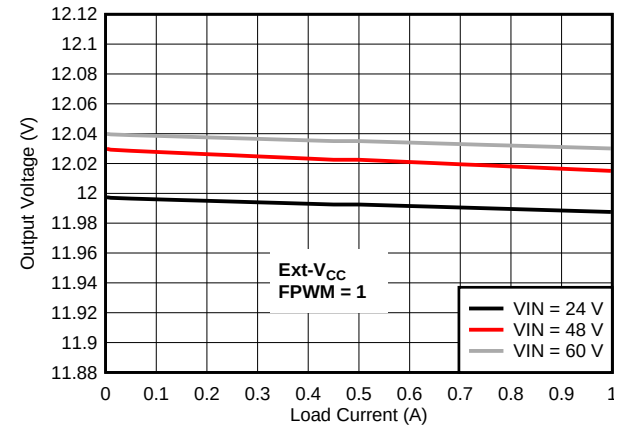
When selecting the DCM mode setting using the Jumper (**JP1**) see Table 2, the internal emulated ripple mode is enabled. When operating in this mode, there is no need to add the external ESR resistor in series with the output capacitors or the external ripple injection circuit (see Section 7 for more details). The internal emulated ripple is sufficient to maintain steady-state and dynamic stability while operating in this mode. In a typical buck application at T_J > 125°C and FPWM = 0, with the input voltage VIN > 72 V and the V_{CC} externally supplied add a BST resistor, R2 (recommended > 3Ω) in series with the BST capacitor (see Figure 21). This protects the internal bootstrap diode during a full load transient operation.

An external voltage can be supplied to the VCC pin in the range of 9 V to 13 V, for improved efficiency requirements. In that case, the diode D1 must be appropriately populated. The user can keep diode D1 populated on board and install/uninstall the jumper **J4** in order to estimate the difference in efficiency, with and without the external V_{CC} supply. More details about the diode D1 are given in the Section 6.

Table 2. FPWM Pin Mode

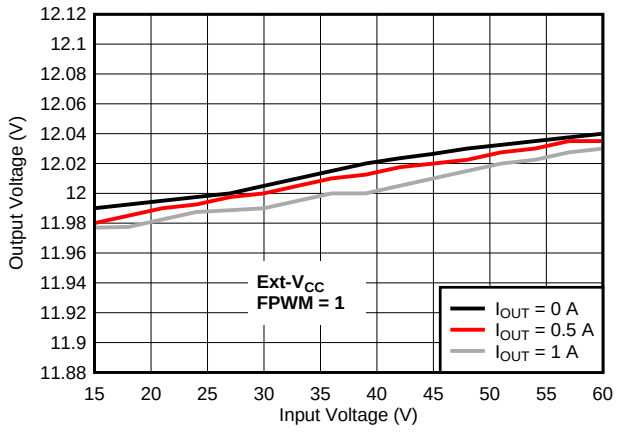
JP1 Setting	Logic Stage	Description
DCM or Floating (High Z) (Pin 2 - Pin 3: DCM)	0	The FPWM pin is grounded or left floating. Populate resistor R2 appropriately. DCM with the pulse skipping mode at light load enabled. No external ripple injection circuit needed.
FPWM (VCC) (Pin 2 - Pin 1: FPWM)	1	The FPWM pin is connected to VCC. External Ripple Injection circuit needed. CCM mode enabled over the entire load range.

4 Typical Performance Curves



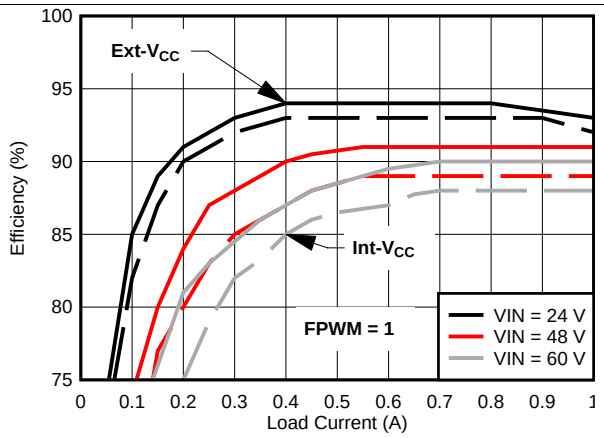
V_{OUT} - V_{CC} diode connected FPWM = 1 F_{SW} = 300kHz

Figure 2. Load Regulation



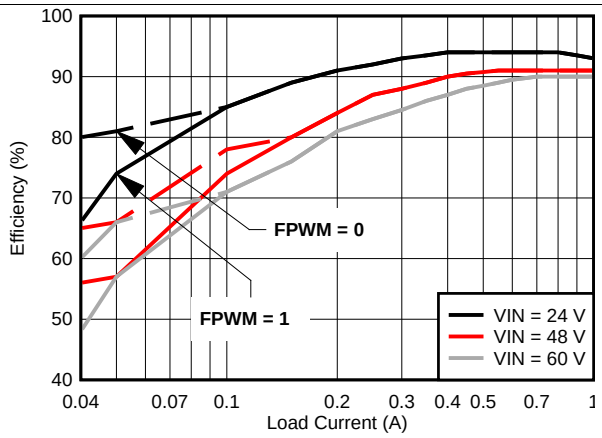
V_{OUT} - V_{CC} diode connected FPWM = 1 F_{SW} = 300kHz

Figure 3. Line Regulation



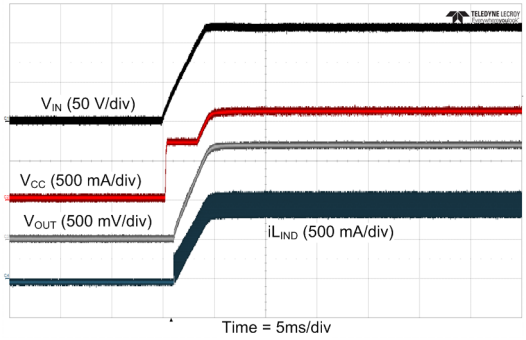
V_{OUT} = 12 V FPWM = 1 F_{SW} = 300kHz

Figure 4. Efficiency vs. I_{OUT}



V_{OUT} - V_{CC} diode connected F_{SW} = 300kHz V_{OUT} = 12 V

Figure 5. Efficiency Comparison Between Forced CCM and DCM



V_{IN} = 48 V F_{SW} = 300kHz FPWM = 1 V_{OUT} - V_{CC} diode connected

Figure 6. Startup at Full Load

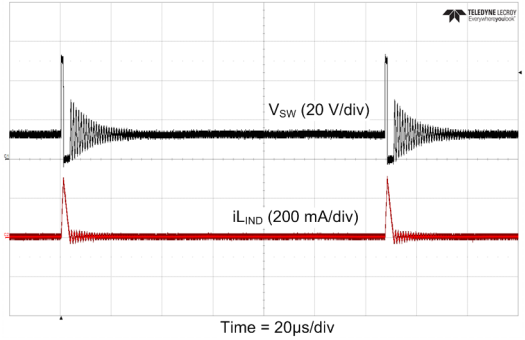


Figure 7. Steady State at V_{IN} = 48 V and FPWM = 0 (no load)

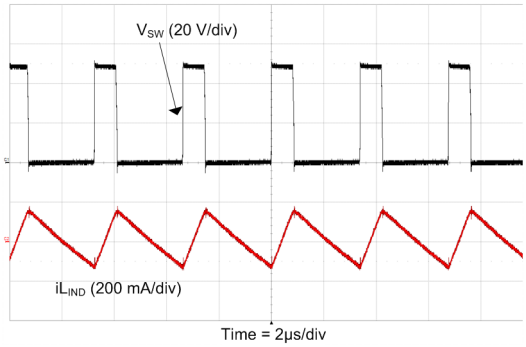
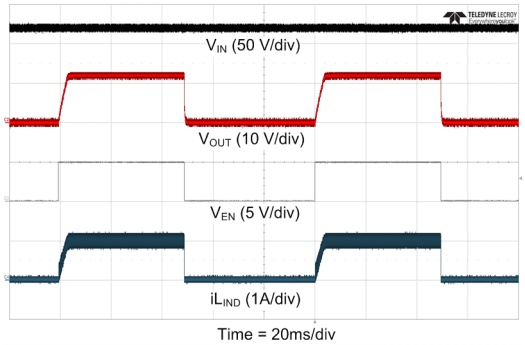
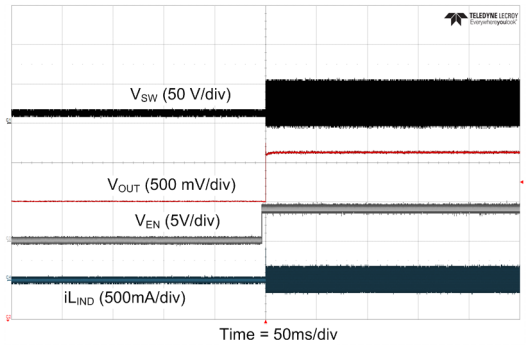


Figure 8. Steady State at V_{IN} = 48 V and FPWM = 1 (no load)



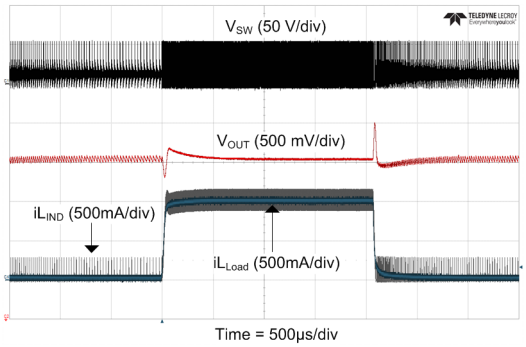
V_{IN} = 48 V F_{SW} = 300kHz FPWM = 1 V_{OUT} - V_{CC} diode connected

Figure 9. EN/UVLO Startup/Shutdown at Full Load



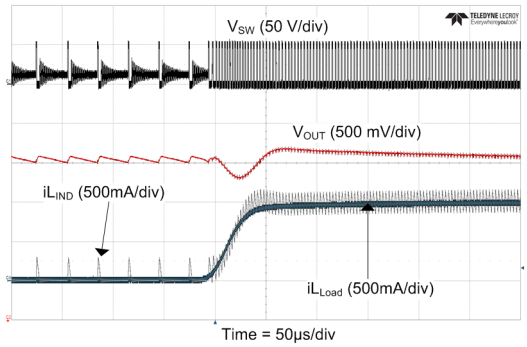
V_{IN} = 48 V F_{SW} = 300kHz FPWM = 1 V_{OUT} - V_{CC} diode connected

Figure 10. Pre-Bias Startup at No Load



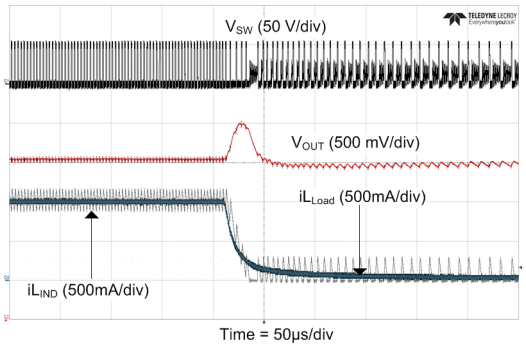
V_{IN} = 48 V FPWM = 0 F_{SW} = 300kHz

Figure 11. Load Transient (I_{Load} = No Load to Full Load to No Load) in DCM



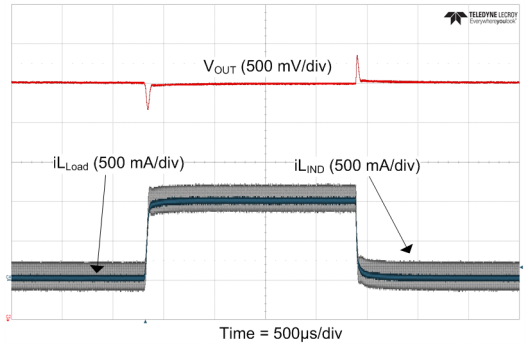
V_{IN} = 48 V FPWM = 0 F_{SW} = 300kHz V_{OUT} = 12 V

Figure 12. Load Transient (I_{Load} = No Load to Full Load) in DCM



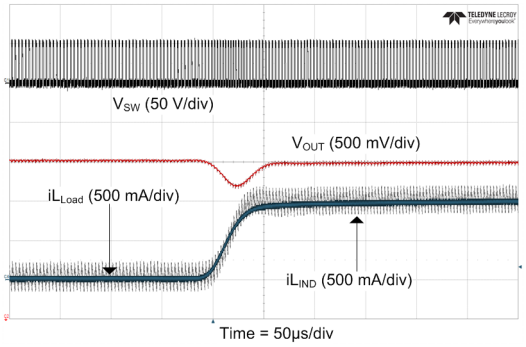
V_{IN} = 48 V FPWM = 0 F_{SW} = 300kHz V_{OUT} = 12 V

Figure 13. Load Transient (I_{Load} = Full Load to No Load) in DCM



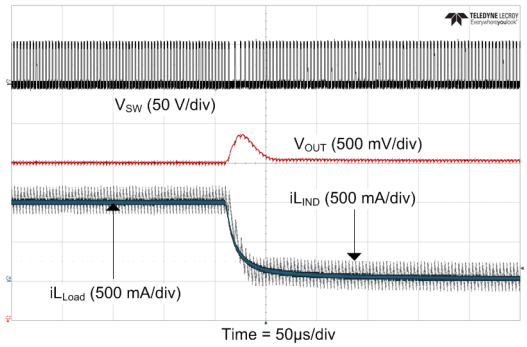
V_{IN} = 48 V FPWM = 1 F_{SW} = 300kHz V_{OUT} = 12 V

Figure 14. Load Transient (I_{Load} = No Load to Full Load to No Load) in CCM



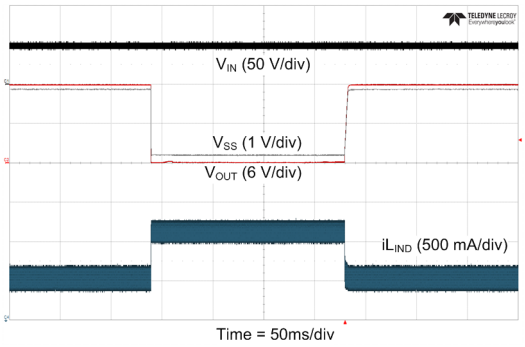
V_{IN} = 48 V FPWM = 1 F_{SW} = 300kHz V_{OUT} = 12 V

Figure 15. Load Transient (I_{Load} = No Load to Full Load) in CCM



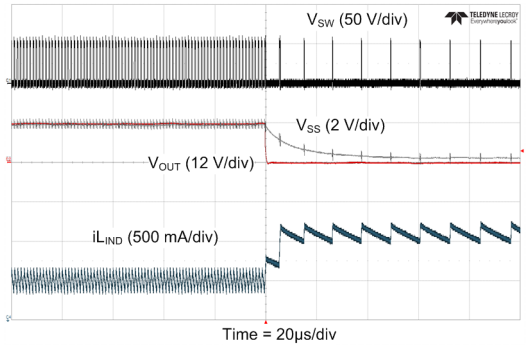
V_{IN} = 48 V FPWM = 1 F_{SW} = 300kHz V_{OUT} = 12 V

Figure 16. Load Transient (I_{Load} = Full Load to No Load) in CCM



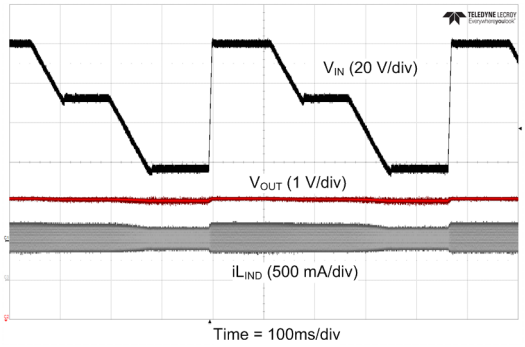
V_{IN} = 48 V F_{SW} = 300kHz V_{OUT} = 12 V

Figure 17. Short Circuit (I_{Load} = Full Load to Short to Full Load)



V_{IN} = 48 V F_{SW} = 300kHz V_{OUT} = 12 V

Figure 18. Short Circuit (I_{Load} = Full Load to Short)



F_{SW} = 300kHz V_{OUT} = 12 V I_{Load} = 500 mA

Figure 19. Line Transient ($36V_{IN}$-$100V_{IN}$-$72V_{IN}$)

5 LM5161 Buck EVM Schematic

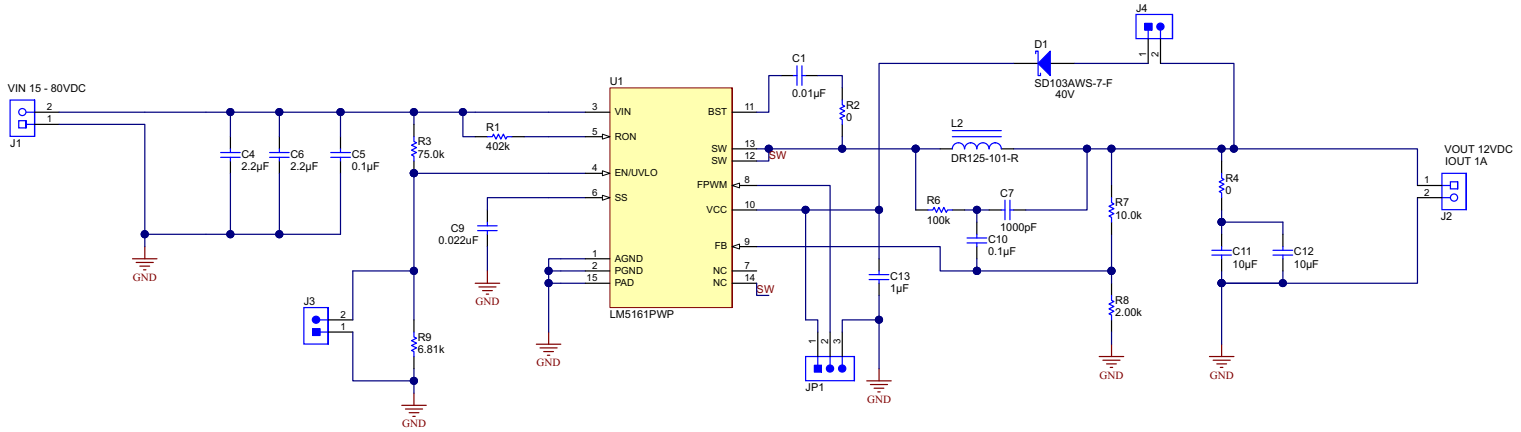


Figure 20. LM5161 Synchronous Buck EVM Schematic

6 LM5161 Buck EVM Bill of Materials

Table 3. LM5161 Buck EVM Bill of Materials for 300 kHz Configuration

ITEM	MFR	MFG. PART NUMBER	PACKAGE	VALUE
C4, C6	MuRata	GRM31CR72A225KA73L	1206	CAP, CERM, 2.2 µF, 100V, X7R
C5	MuRata	GRM188R72A104KA35D	0603	CAP, CERM, 0.1 µF, 100V, X7R
C9	MuRata	GRM188R71C223KA01D	0603	CAP, CERM, 0.022 µF, 16V, ± 10%, X7R
C1	MuRata	GRM188R71C103KA01D	0603	CAP, CERM, 0.01 µF, 16V, ± 10%, X7R
C13	MuRata	GRM188R71E105KA12D	0603	CAP, CERM, 1 µF, 25V, ± 10%, X7R
C11, C12	TDK	C3216X7R1E106M160AE	1206	CAP CER 10 µF, 25V, X7R
JP1	Wurth Elektronik	61300311121		Header, 2.54 mm, 3x1, Gold, TH
J3, J4	Wurth Elektronik	61300211121		Header, 2.54 mm, 2x1, Gold, TH
J1, J2	Phoenix Contact	1727010		Conn Term Block, 2POS, 3.81mm, TH
L2	Eaton	DR125-101-R	12.5 mm x 12.5 mm x 6 mm	Fixed Ind 100 µH, 1.78A , 170 mΩ
	Wurth Elektronik (Alternative Part)	784770101	12.5 mm x 12.5 mm x 8 mm	Fixed Ind 100 µH, 2.1A , 144 mΩ
R1	Vishay-Dale	CRCW0603402KFKEA	0603	RES, 402 k, 1%, 0.1 W
R2	Vishay-Dale	CRCW06030000Z0EA	0603	RES, 0, 5%, 0.1 W
R3	Vishay-Dale	CRCW060375K0FKEA	0603	RES, 75.0 k, 1%, 0.1 W
R4	Vishay-Dale	CRCW08050000Z0EA	0805	RES, 0, 5%, 0.125 W
R9	Vishay-Dale	CRCW06036K81FKEA	0603	RES, 6.81 k, 1%, 0.1 W
R6	Vishay-Dale	CRCW0603100KFKEA	0603	RES, 100 k, 1%, 0.1 W
R7	Vishay-Dale	CRCW060310K0FKEA	0603	RES, 10.0 k, 1%, 0.1 W
R8	Vishay-Dale	CRCW06032K00FKEA	0603	RES, 2.00k, 1%, 0.1W
U1	Texas Instruments	LM5161PWPR	4.4 mm x 5.0 mm HTSSOP-14	
C7	MuRata	GRM188R72A102KA01D	0603	CAP, CERM, 1000 pF, 100 V, ± 10%, X7R
C10	MuRata (Unpopulated if FPWM = 0)	GCM188R71H104KA57D	0603	CAP, CERM, 0.1 µF, 50 V, ± 10%, X7R
D1	Diodes Inc.	SD103AWS-7-F	SOD-323	Diode, Schottky, 40V, 0.35A

7 LM5161 Buck EVM PCB Layout

Figure 21 to Figure 24 show the board layout details for the LM5161 Buck EVM. When using the LM5161 in FPWM with Type 3 external ripple injection circuit, the ESR resistor (R4) must be substituted with a 0Ω resistor) and the placeholders for the R6, C7 and C10 must be populated appropriately. The oscilloscope snapshots in the Section 4 are captured with C10 set at 0.01µF. If using the Type 1 external ripple injection circuit, the ESR resistor (R4) must be calculated and placed correctly. However, when using the R4 resistor, C10 must be removed. The resistor R2 can remain as a 0Ω resistor in both the external ripple injection circuit cases.

When using the LM5161 in the DCM mode (FPWM = 0) there is no need for the ESR resistor or the external ripple injection circuit as mentioned earlier. However, it is recommended to set R2 (> 3Ω) in series with the BST capacitor (see Figure 21), in order to protect the internal VCC-BST bootstrap diode during a full load transient.

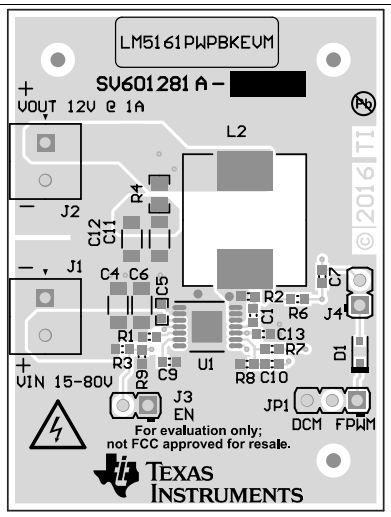


Figure 21. EVM Component View with LM5161

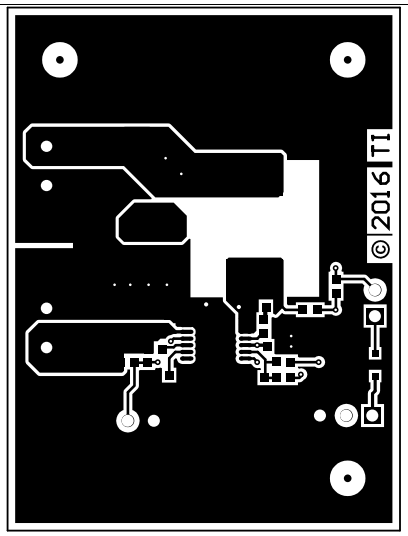


Figure 22. EVM Top Copper View with LM5161

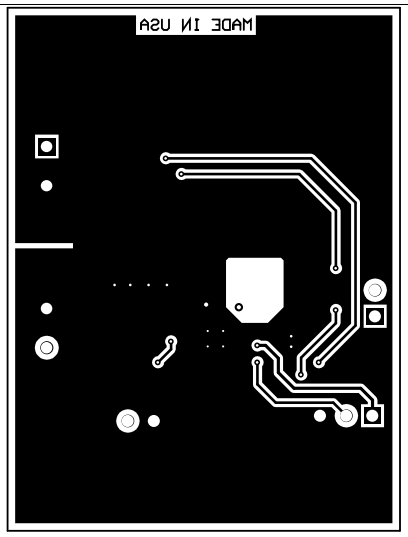


Figure 23. EVM Bottom Copper View with LM5161

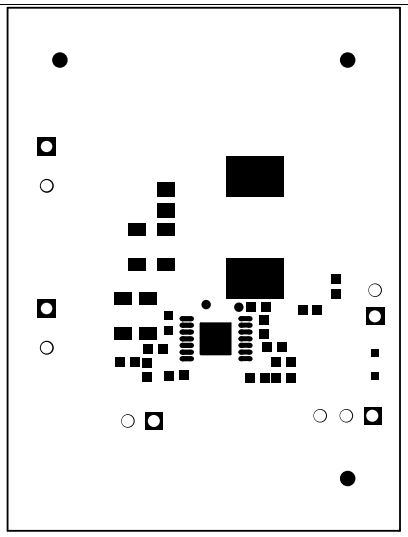


Figure 24. EVM Top Solder Mask with LM5161

Revision History

Changes from Original (August 2016) to A Revision **Page**

- Changed datasheet crossreference to LM5161. 7
- Changed Orderable name to LM5161PWPR 12

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   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 and conditions 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 and conditions 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 any defects that are 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. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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.

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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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。
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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

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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.

6. *Disclaimers:*

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8. *Limitations on Damages and Liability:*

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