Using the UCC28881EVM-680

User's Guide

Literature Number: SLUUBB6A
November 2015–Revised December 2015

Offline High-Side Buck Converter Evaluation Module (EVM)

1 Introduction

The UCC28881EVM-680 evaluation module (EVM) is an offline high-voltage buck-type power supply that provides 13 V_{DC} at a maximum output of 225 mA. The input accepts a voltage range of 85 V_{AC} to 265 V_{AC}.

2 Description

The EVM uses the UCC28881 low quiescent current switcher device. This device integrates a 700-V FET and controller into one SOIC7 package. The device also features a high-voltage current source, enabling start-up and operation directly from the rectified mains voltage. The low quiescent current of the device enables very high efficiency in non-isolated high-side buck low-power converter.

The PWM signal generation is based on a maximum constant ON time concept and each ON pulse is followed by a minimum OFF time to ensure the power MOSFET is not continuously driven in the ON state. The PWM signal is AND gated with the signal from a current limiter. The AND gated signal controls the power MOSFET through a driver. Thereby no internal clock is required, and the switching of the power MOSFET is load dependent. The device is also protected from failure conditions with thermal shutdown, under-voltage lockout, soft start and overload protection. Please refer to the UCC28881, (SLUSC05), data sheet for details.

2.1 Applications

The UCC28881 is suited for use in non-isolated off-line systems requiring high efficiency and advanced fault protection features. Typical applications include:

- Home Appliances
- White Goods
- E Metering
- Home Automation
- Infrastructure
- LED Lighting

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2.2 Features

The UCC28881EVM-680 features include:

- Single13-V Output
- No Load to 225-mA Load Range
- Universal Off-Line Input Voltage Range
- Overload and Output Short-Circuit Protection
- Controlled Start Up and Restart After Fault Protection

CAUTION

High voltage levels are present on the evaluation module whenever it is energized. Proper precautions must be taken when working with the EVM. The large bulk capacitors, C1 and C2 must be completely discharged before the EVM can be handled. Serious injury can occur if proper safety precautions are not followed.

3 Electrical Performance Specifications

Table 1. UCC28881EVM-680 Electrical Specifications

PARAMETER		DESCRIPTION	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS						
V_{IN}	Input voltage		85	115/230	265	V_{RMS}
f_{LINE}	Line frequency		47	50/60	64	Hz
V_O	Output voltage	13-V output target at full load over line and load output can drift	12.5		17.9	V
I_{OUT}	Output current				225	mA
P_{OUT}	Output power				2.9	W
O_{TR}	Operating temperature range	I_{OUT} < or = 225 mA	0	25	40	°C
V_{OR}	Output ripple voltage				400	mV
η	Efficiency	I_{OUT} = 225 mA, V_{IN} = 230 V/115 V		80%		

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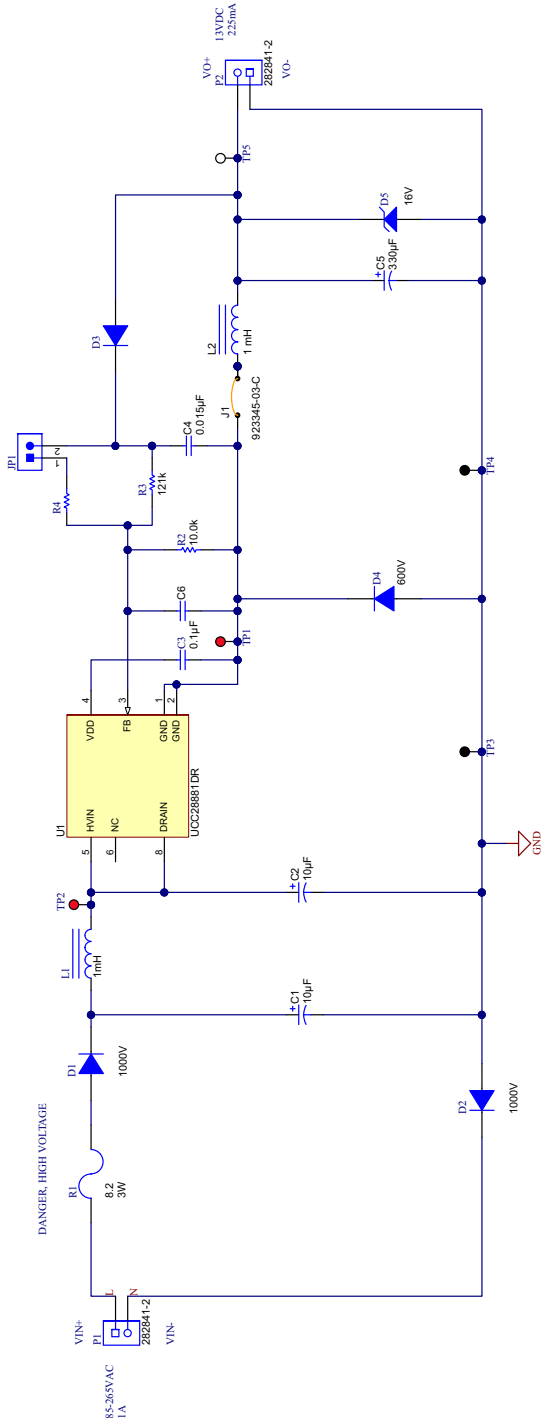
4 Schematic



No parametric value means the device is not populated.

Figure 1. UCC28881EVM-680 Power Stage Schematic

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5 Circuit Description

The UCC28881EVM-680 is a non-isolated AC-to-DC high-side buck configuration with direct feedback. The EVM, on the input side, has a half-wave rectifier assembled for rectification of AC-to-DC, followed by an EMI filter.

NOTE: The GND node is one diode drop (D2) above the input neutral (N) node.

In addition to the UCC28881 device, the EVM holds the following key components:

- A Half-Wave Rectifier (D1, D2)
- EMI Filter (L1, C1, C2)
- Freewheeling Diode (D4)
- 16-V Zener Clamp to Regulate no Load Output Voltage (D5)
- Inductor (L2)
- Load Capacitor (C5)
- Feedback Path (C4, D3, R2, R3, R4, JP1)
- VAC Input Connector (P1)
- VDC Output Connector (P2)

6 Test Points

Table 2. UCC28881EVM-680 Test Points

DESIGNATOR	DESCRIPTION
TP1	Buck switch node
TP2	High voltage rectified DC
TP3	GND
TP4	GND
TP5	VOUT

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7 Recommended Basic Test Equipment

AC Input Source: The input source is an isolated variable AC source capable of supplying between 85 V_{RMS} and 265 V_{RMS} at no less than 5 W and connected as shown in Figure 2. For accurate efficiency calculations, a power meter (PM1) should be inserted between the AC source and the EVM. For highest accuracy, connect the voltage terminals of the power meter directly across the power source.

NOTE: Connecting the voltage terminals directly to the EVM results in a small current error. This is very significant when measuring no-load power.

Load (R1): The UCC28881EVM-680 is capable of delivering 225 mA of output current.

NOTE: The output is not isolated from the AC and the electronic load must be capable of operating from a high-voltage input.

Power Meter (PM1): The power analyzer (PM1) is capable of measuring low-input current, typically less than 100 µA, and a long averaging mode if low-power standby mode input power measurements are to be taken. An example of such an analyzer is the Yokogawa WT210 Digital Power Meter.

Multimeters (V1, V2, A1): Three digital multimeters are used to measure the regulated output voltage and load current.

Oscilloscope: A digital or analog oscilloscope with a 500-MHz scope probe is recommended.

Recommended Wire Gauge: A minimum of AWG 24 wire is recommended. The wire connections between the AC source and the EVM, and the wire connections between the EVM and the load should be less than two feet long.

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8 Test Setup

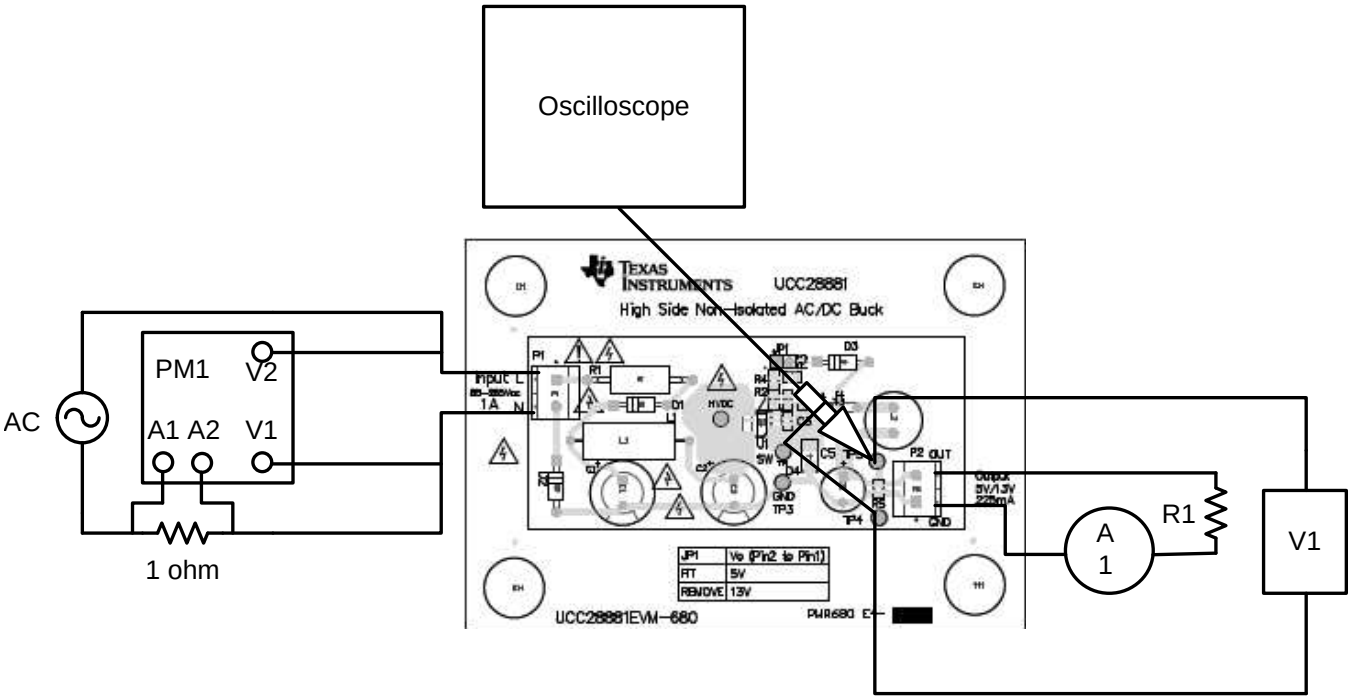

Figure 2. Test Setup

9 Power On/Off Procedure

1. The EVM should only be handled by persons trained in the design/testing and evaluation of offline power supplies.
   (a) Offline voltage 0 V_{RMS} to 265 V_{RMS}
   (b) DC voltages up to 380 V_{DC}
2. All necessary connections must be made before applying power.
3. After the EVM is powered down, monitor the voltage across the high-voltage DC bulk voltage.
   (a) This is the voltage across TP2 and TP3.

NOTE: Do not handle this EVM or disconnect the setup if the voltage across these pins are greater than 50 V_{DC} or if the AC voltage is still applied to the EVM.

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10 Test Data

10.1 Line/Load Regulation and Efficiency Test Data

Table 3. Line/Load Regulations and Efficiency Test Data

P_{OUT}	I_{LOAD}	V_{IN}	V_{OUT}	I_{OUT}	P_{IN}	EFFICIENCY
0%	0.000	115	16.510	0.000	0.315 (1)	0%
10%	0.022	115	15.501	0.022	0.403	85%
22%	0.050	115	13.849	0.050	0.847	82%
33%	0.075	115	13.400	0.075	1.238	81%
44%	0.100	115	13.174	0.100	1.623	81%
67%	0.150	115	12.949	0.150	2.412	81%
100%	0.225	115	12.795	0.225	3.599	80%
0%	0.000	230	16.515	0.000	0.361 (1)	0%
10%	0.022	230	15.610	0.022	0.441	78%
22%	0.050	230	13.901	0.050	0.872	80%
33%	0.075	230	13.438	0.075	1.256	80%
44%	0.100	230	13.201	0.100	1.636	81%
67%	0.150	230	12.971	0.150	2.402	81%
100%	0.225	230	12.822	0.225	3.581	81%

(1) Power dissipation at no load is mostly due to Zener clamp D5. This Zener diode is required to keep the output in regulation under no load conditions, due to the sample and hold technique that was used in this design. The power dissipation of D5 under no load is roughly 300 mW.

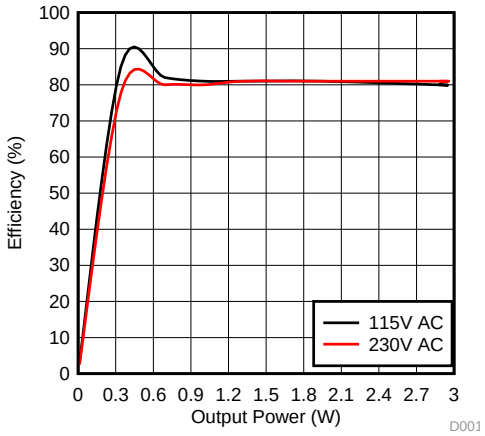

Figure 3. Efficiency Graph

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10.2 Transient Response

CH1 = V_{OUT}

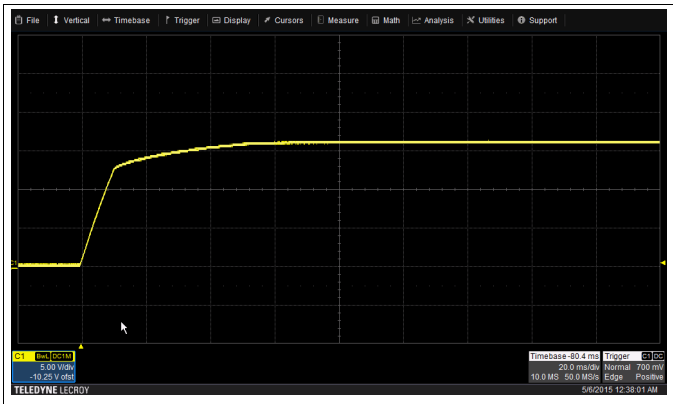

Figure 4. V_{IN} = 85 V_{RMS}, I_{OUT} = 0 A

Figure 5. V_{IN} = 85 V, I_{OUT} = 225 mA

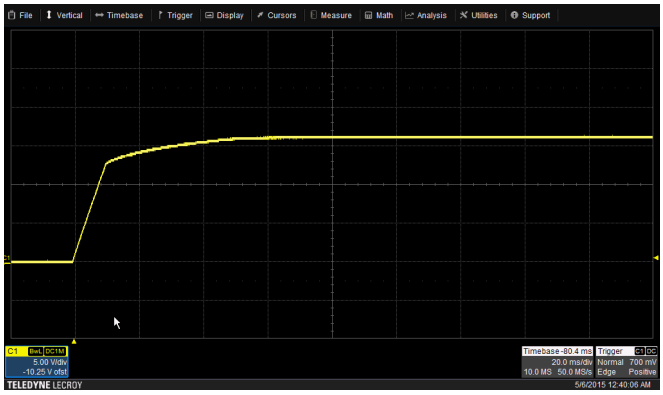

Figure 6. V_{IN} = 265 V_{RMS}, I_{OUT} = 0 A

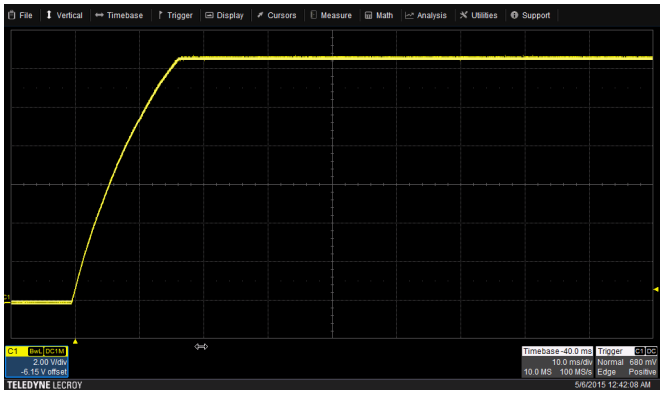

Figure 7. V_{IN} = 265 V, I_{OUT} = 225 mA

10.3 Load Transient Response

CH1 = V_{OUT}, CH4 = I_{OUT}, 500 mA/10 mV

Load step 0.022 A to 0.225 A

Figure 8. V_{IN} = 85 V

Figure 9. V_{IN} = 265 V_{RMS}

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10.4 Output Ripple Voltage

CH1 = V_{OUT}

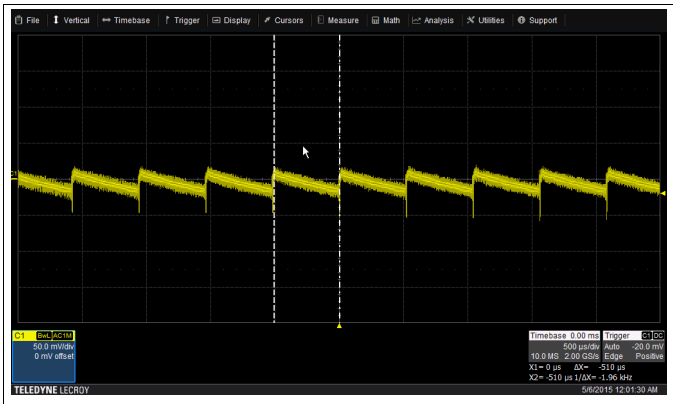

Figure 10. V_{IN} = 85 V, I_{OUT} = 0 A

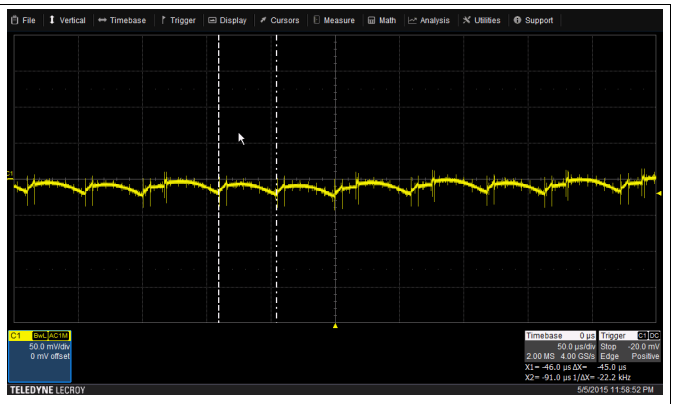

Figure 11. V_{IN} = 85 V, I_{OUT} = 0.225 A

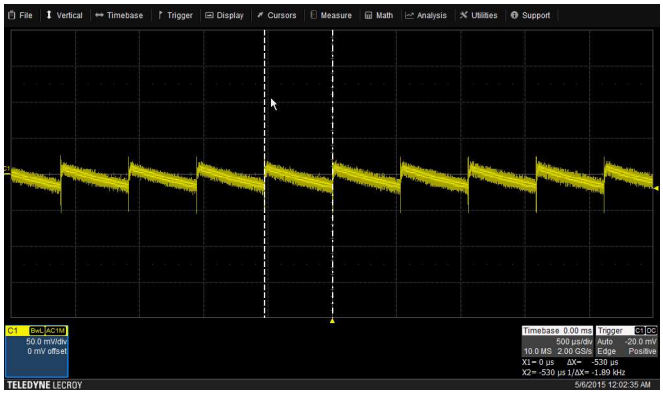

Figure 12. V_{IN} = 265 V, I_{OUT} = 0 A

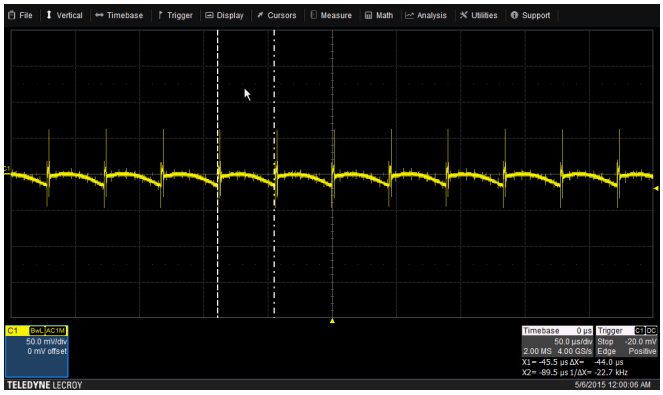

Figure 13. V_{IN} = 265 V, I_{OUT} = 0.225 A

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10.5 Audible Noise

When evaluating this EVM it's apparent that at full load the EVM runs quiet, but as the load decreases the EVM becomes noticeably audible. This is because the converter at full load operates with an inductor ripple current frequency/output ripple voltage at frequency of roughly 22 kHz, which is out of the audible range for most humans. However as load decreases the inductor goes heavy into discontinuous mode operation and the output frequency drops. When the output frequency drops below 18 kHz to 16 kHz, audible noise can be heard. To illustrate this behavior the scope plots of Figure 14 (Full Load) and Figure 15 (60% Load) were taken. Ch1 is the output voltage of the EVM, where CH4 is the inductor (L2) current (500 mA/10 mV). At full load the inductor ripple and output ripple voltage run at a frequency of roughly 22 kHz (Figure 14), which is not audible. However, as the load decreases the inductor ripple and output ripple frequency decreases to the point where the EVM enters the audible frequency range and is audible (Figure 15).

NOTE: It is normal for this control methodology to become audible as the load decreases. It is more suited for end products that operate heavily loaded (75% to 100%) and no load.

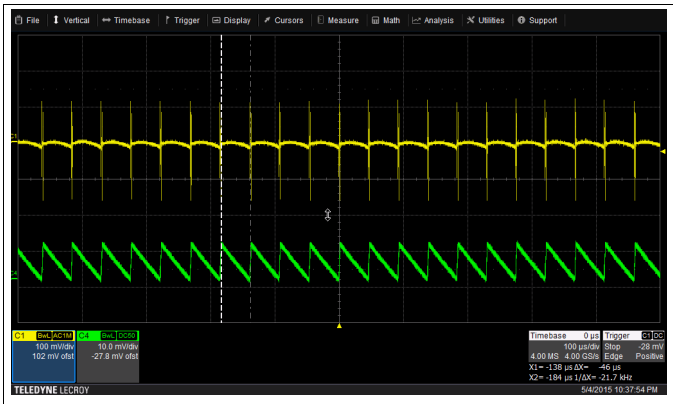

Figure 14. I_{OUT} = 225 mA

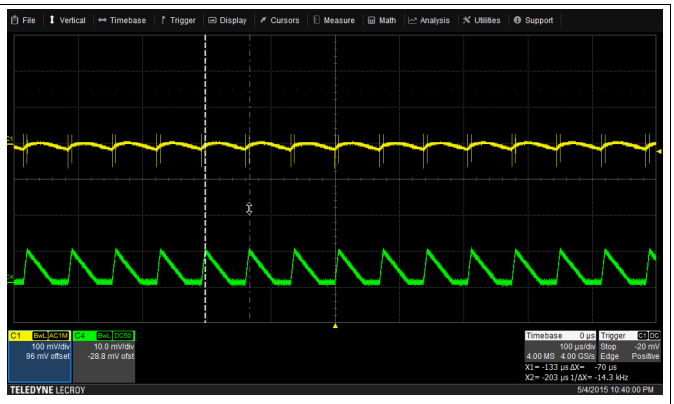

Figure 15. I_{OUT} = 138 mA

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11 Assembly Drawing/Layout

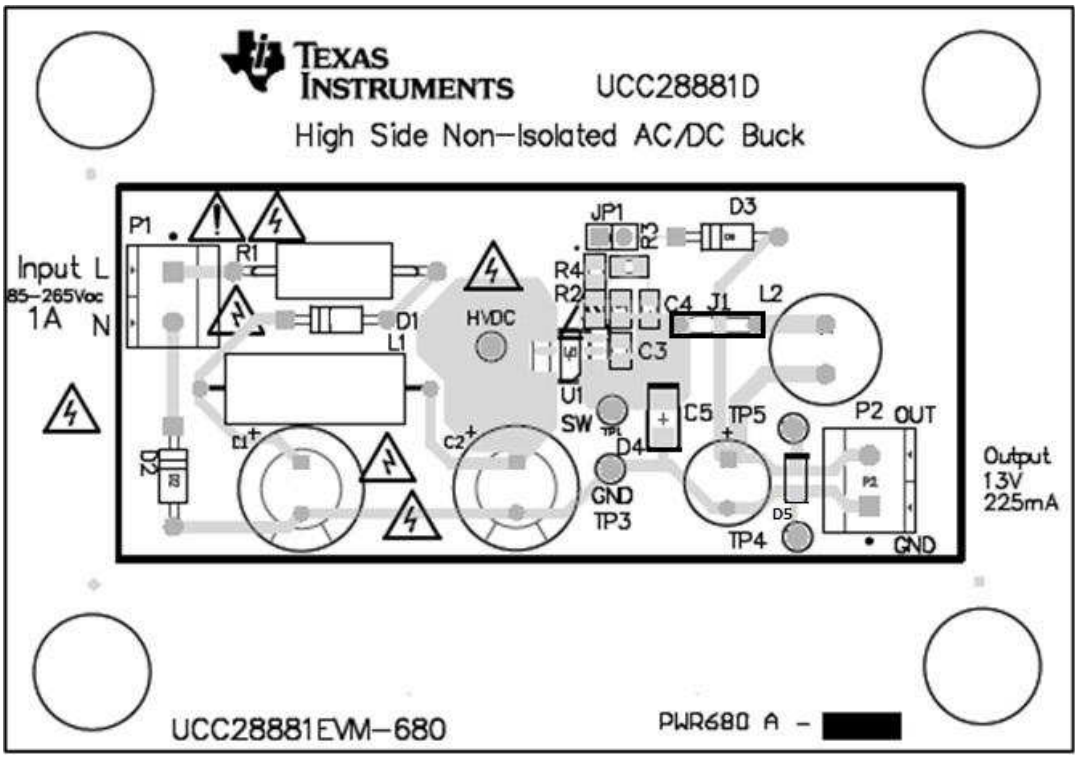

Figure 16. UCC28881EVM-680 Assembly Drawing/Layout

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12 List of Materials

Table 4. UCC28881EVM-680 List of Materials

QTY	DES	DESCRIPTION	PART NUMBER	MANUFACTURER
2	C1, C2	Capacitor, aluminum, 10 µF, 450 V, ±20%, 2.864788 Ω, TH	EEUED2W100	Panasonic
1	C3	Capacitor, ceramic, 0.1 µF, 50 V, ±10%, X7R, 0805	C0805C104K5RACTU	Kemet
1	C4	Capacitor, ceramic, 0.015 µF, 50 V, ±10%, X7R, 0805	C0805C153K5RACTU	Kemet
1	C5	Capacitor, aluminum, 330 µF, 35 V, ±20%, 0.03 Ω, TH	EEU-FM1V331L	Panasonic
0	C6	Capacitor, ceramic, 0.01 µF, 100 V, ±10%, X7R, 0805	C0805C103K1RACTU	Kemet
2	D1, D2	Diode, P-N, 1000 V, 1 A, TH	1N4007	Fairchild Semiconductor
1	D3	Diode, standard recovery rectifier, 600 V, 1 A, TH	1N4006-T	Diodes Inc.
1	D4	Diode, ultrafast, 600 V, 1 A, SMA	STTH1R06A	ST Microelectronics
1	D5	Diode, Zener, 16 V, 500 mW, SOD-123	MMSZ4703T1G	ON Semiconductor
4	H1, H2, H3, H4	Bumpon, hemisphere, 0.44 inch x 0.20 inch, clear	SJ-5303 (CLEAR)	3M
0	J1	Jumper wire, 300 mil spacing, orange, pkg of 200	923345-03-C	3M
0	JP1	Header, TH, 100 mil, 2 inch x 1 inch, gold plated, 230 mil above insulator	TSW-102-07-G-S	Samtec
1	L1	Inductor, wirewound, ferrite, 1 mH, 0.2 A, 2.3 Ω, TH	5800-102-RC	Bourns
1	L2	Inductor, wirewound, ferrite, 1 mH, 0.4 A, 1.2 Ω, TH	7447471102	Wurth Elektronik
2	P1, P2	Terminal block, 2 inch x 1 inch, 5.08 mm, TH	282841-2	TE Connectivity
1	R1	Resistor, 8.2 Ω, 5%, 3 W, fusible, TH	PWR4522AS8R20JA	Bourns
1	R2	Resistor, 10.0 kΩ, 1%, 0.125 W, 0805	ERJ-6ENF1002V	Panasonic
1	R3	Resistor, 121 kΩ, 1%, 0.125 W, 0805	ERJ-6ENF1213V	Panasonic
0	R4	Resistor, 61.9 kΩ, 1%, 0.125 W, 0805	ERJ-6ENF6192V	Panasonic
1	SH-JP1	Shunt, 100 mil, flash gold, black 1 inch x 2 inch	SPC02SYAN	Sullins Connector Solutions
2	TP1, TP2	Test point, miniature, red, TH	5000	Keystone
2	TP3, TP4	Test point, miniature, black, TH	5001	Keystone
1	TP5	Test point, miniature, white, TH	5002	Keystone
1	U1	700-V Lowest Quiescent Current Off-Line Switcher, D0007A	UCC28881DR	Texas Instruments
0	PCB	Printed circuit board	PWR680	Any

Revision History

Changes from Original (November 2015) to A Revision **Page**

- Changed output voltage MIN and MAX specifications..... 3
- Added power dissipation note. 8

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

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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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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.

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