Using the UCC28880EVM-616

User's Guide

Literature Number: SLUUB56C
July 2014–Revised February 2017

UCC28880EVM-616 High-Side Buck Evaluation Module

1 Introduction

The UCC28880EVM-616 evaluation module is an offline high-voltage buck-type power supply that provides 13 V_{DC} at a maximum output of 100 mA. The input accepts a voltage range of 85 V_{AC} to 265 V_{AC}. The evaluation module also has the option to deliver 5-V_{DC} output using a simple jumper arrangement for the purpose of quick demonstration (additional power-stage optimization needed for optimal 5-V output performance).

The evaluation module uses the UCC28880 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 converters. Additional features are low standby power and a minimum number of external components.

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.

2 Applications

The UCC28880 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

3 Features

The UCC28880EVM-616 features include:

- Preset Output Voltage of ~13 V (JP1 not installed)
  (modify to ~5-V output voltage by installing jumper J1)
- No Load to 100-mA Load Range
- Universal Off-Line Input Voltage Range
- Meets EN55022 ClassB Conducted Emissions Requirements
- Overload and Output Short-Circuit Protection
- Thermal Shutdown
- 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.

4 Electrical Performance Specifications

Table 1. UCC28880EVM-616 Electrical Performance Specifications (13-V Output)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics						
V_{IN}	Input voltage		85	115/230	265	V
f_{LINE}	Frequency		47	50/60	64	Hz
	No load power	V_{IN} = 115 V/230 V, I_{OUT} = 0 mA		27/38		mW
I_{IN}	Input current	V_{IN} = 85 V, I_{OUT} = 100 mA		50	100	mA
Output Characteristics						
V_{OUT1} (1)	Output voltage	V_{IN} = 85 V to 265 V, I_{OUT} = 0 mA to 100 mA	12.65	12.6	13.25	V
I_{OUT}	Maximum output current	V_{IN} = 85 V to 265 V		100		mA
I_{OUT}	Output current range	V_{IN} = 85 V to 265 V	0		100	mA
V_{OUT_ripple}	Output voltage ripple	V_{IN} = 85 V to 265 V, I_{OUT} = 0 mA to 100 mA		200		mVpp
P_{OUT}	Output power	V_{IN} = 85 V to 265 V		1.3		W
Systems Characteristics						
h	Maximum efficiency	V_{IN} = 115 V/230 V, I_{OUT} = 100 mA	-	80/82	-	%
TOP	Operating temperature range	V_{IN} = 85 V to 265 V, I_{OUT} = 0 mA to 100 mA	0	25	40	°C
Environmental						
	Conducted EMI				Meets CISPR22B/EN55022B	
Mechanical Characteristics						
W	Dimensions	Width		3.5		in
L		Length		5		in
H		Component height		0.75		in

(1) JP1 removed

Table 2. UCC28880EVM-616 Electrical Performance Specifications (5-V Output)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics						
V_{IN}	Input Voltage		85	115/230	265	V
f_{LINE}	Frequency		47	50/60	64	Hz
	No Load Power	V_{IN} = 115 V/230 V, I_{OUT} = 0 A		14/24		mW
I_{IN}	Input Current	V_{IN} = 85 V, I_{OUT} = 100 mA		25	50	mA
Output Characteristics						
V_{OUT1} (1)	Output Voltage	V_{IN} = 85 V to 265 V, I_{OUT} = 0 mA to 100 mA	4.25	4.35	6.35	V
I_{OUT}	Maximum Output Current	V_{IN} = 85 V to 265 V		100		mA
I_{OUT}	Output Current Range	V_{IN} = 85 V to 265 V	0		100	mA
$V_{OUT(ripple)}$	Output Voltage Ripple	V_{IN} = 85 V to 265 V, I_{OUT} = 100 mA		150		mVpp
P_{OUT}	Output Power	V_{IN} = 85 V to 265 V		0.43		W
Systems Characteristics						
h	Maximum Efficiency	V_{IN} = 115 V/230 V, I_{OUT} = 100 mA		62%/61 %		
TOP	Operating Temperature Range	V_{IN} = 85 V to 265 V, I_{OUT} = 0 mA to 100 mA	0	25	40	°C
Environmental						
	Conducted EMI			Meets CISPR22B/EN55022B		
Mechanical Characteristics						
W	Dimensions	Width		3.5		in
L		Length		5		in
H		Component height		0.75		in

(1) JP1 inserted.

5 Schematic

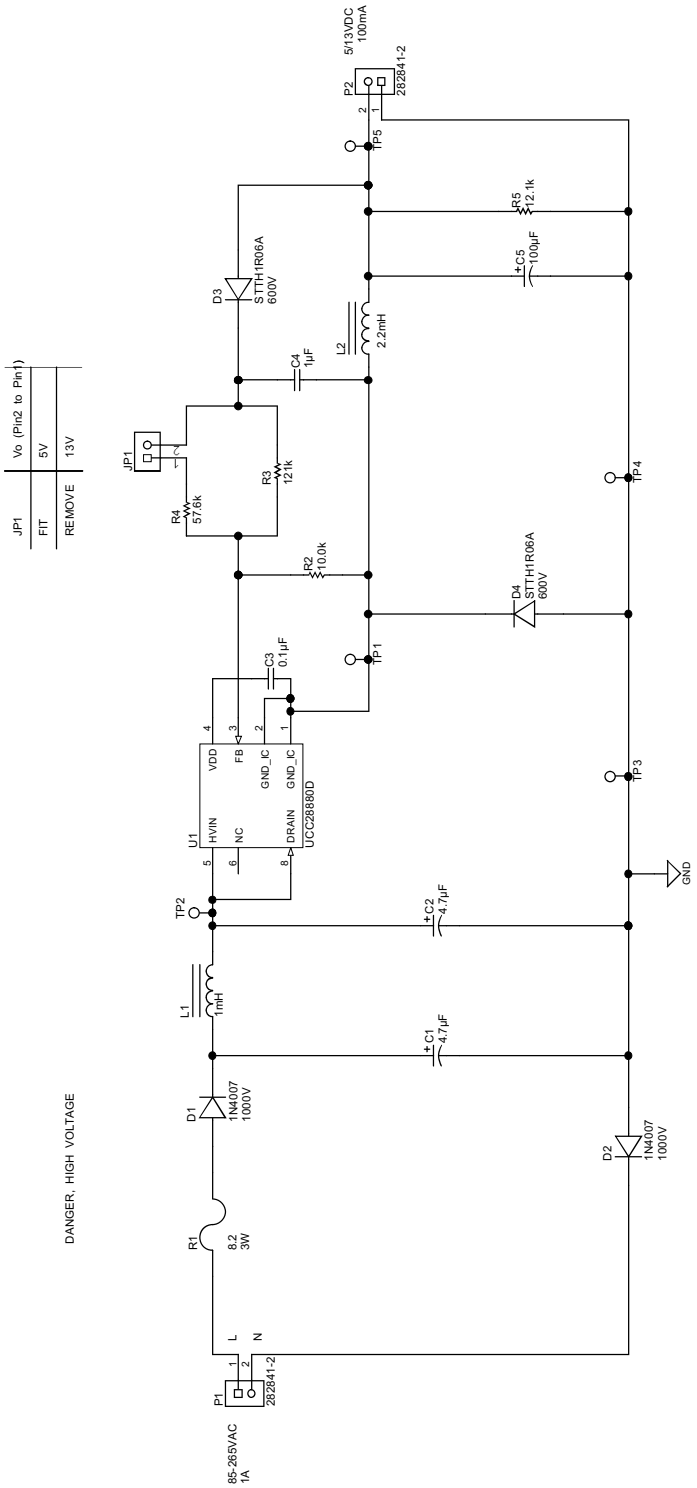

Figure 1. UCC28880EVM-616 Schematic

6 Circuit Description

The UCC28880EVM-616 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.

The pre-set output voltage is set to ~13 V (typical) if jumper J3 is not connected, or ~5 V (typical) when the jumper is inserted. In the high-side buck configuration the output at OUT pin of connector P2 is positive with respect to GND.

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

In addition to the UCC28880 device, the EVM holds the following key components:

- A Half-Wave Rectifier (D1, D2)
- EMI Filter (L1, C1, C2)
- Freewheeling Diode (D4)
- Inductor (L2)
- Load Capacitor (C5) and Pre-Load Resistor (R5)
- Feedback Path (C4, D5, R2, R3, R4, J3)
- V_{AC} Input Connector (P1)
- V_{DC} Output Connector (P2)

Table 3. UCC28880EVM-616 Board Jumpers

DESIGNATOR	DESCRIPTION	NOTE
JP1	Selecting feedback resistor values to select between 5-V and 13-V output: • When the jumper is inserted, the output is 5 V. • When left open, the output is 13 V.	Output is measured from pin 2 to pin 1 of P2.

Table 4. UCC28880EVM-616 Test Points

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

Table 5. UCC28880EVM616 Board Connectors

CONNECTOR	PIN NUMBER	DESCRIPTION
P1	L (pin1)	AC mains terminal input (line). AC mains input can be connected in either polarity. If DC is fed into this connector, then connect the positive V_{DC} to this node. Warning: This is a high-voltage node.
	N (pin2)	AC main terminal input (neutral). AC Mains input can be connected in either polarity. If DC is fed into this connector, then connect negative V_{DC} to this node. Warning: This is a high-voltage node.
P2	Out (5 V/13 V) (pin1)	Positive output node.
	Gnd (pin2)	Negative output node (one diode drop above the input N).

The UCC28880EVM-616 is configured as a non-isolated AC-to-DC high-side buck converter with direct feedback. The output voltage OUT is referenced to the GND node, which is referenced to the negative high voltage node N. The potential difference between these nodes is equivalent to the voltage drop in diode D2. The output voltage is positive with respect to the GND node. The output voltage at OUT can be selected to be either ~5 V (typical) or ~13 V (typical) with the jumper JP1. See Table 3 for jumper settings to select between the two output voltage levels.

AC input voltage can be fed to the AC input nodes L and N in connector P1. When connecting AC input to P1 it does not matter which way line and neutral are connected to the P1 nodes. When connecting DC input to P1, please verify that polarity is correct, L is the positive node and N the negative node.

The feedback path, consisting of resistors R2 and R3, diode D5 and capacitor C4, sets the output voltage to ~13 V by default when the jumper JP1 is open. The diode D5 is identical to D4, and their voltage drops compensate each other. The feedback is sampling the output voltage level to capacitor C4 during the off state of the integrated HV FET of the UCC28880 and the output voltage is set by the resistors R2 and R3 following the equation:

$$V_{OUT} = \frac{R2 + R3}{R2} \times V_{FB} \quad (1)$$

where V_{OUT} is the output voltage and V_{FB} = 1.0 V is the voltage level at the feedback pin. The current through the external feedback path is set by the total resistance between OUT and GND nodes (resistors R2 through R3):

$$I_{FB} = \frac{V_{OUT}}{R2 + R3} \quad (2)$$

where I_{FB} is the current through the feedback and set to ~100 µA on this board.

When the jumper JP1 is closed, the resistor R4 is connected in parallel with resistor R3, and the output is set to ~5 V. To change either the output voltage or the feedback path current, use the equations above.

There is a pre-loaded resistor (R5), which sets a pre-load of ~1 mA at the output when 13 V is selected. With 5 V output, the preload is ~400 µA. A load of up to 100 mA can be applied to the output.

The design of UCC28880EVM-616 is optimized for 13-V output setting. For 5-V setting, there is additional room for optimization when factors such as audible noise, output voltage ripple, stand-by power etc are considered. The value of the bootstrap capacitor (C4), the impedance of the feedback divider network (R4, R3, R2), and output capacitor (C5) are especially critical. The RC time constant of the bootstrap capacitor and feedback resistor divider network influences voltage on the FB pin, which in turn, influences the burst pattern of switching pulses in the device. By adjusting these components the frequency of the burst pattern can be manipulated higher or lower. This is an effective way to address audible noise emanating from the magnetics and capacitors in the system. A higher RC time constant reduces the frequency of occurrence of burst pulses, which increases the output voltage ripple unless the value of output capacitor is also increased alongside. A lower-time constant increases the frequency of the burst pattern, but a smaller resistor divider impedance increases the stand-by power consumption. These trade-offs have to be considered when designing the power supply.

7 EVM Test Set Up

WARNING

High voltages that may cause injury exist on this evaluation module (EVM). Please ensure all safety procedures are followed when working on this EVM. Never leave a powered EVM unattended.

Figure 2 shows the basic test setup recommended to evaluate the UCC28880EVM-616. Start by applying a low DC voltage (~15 V to 20 V) into the AC input (P1). When connected correctly the output voltage is regulated to ~13 V (positive with respect to GND). Once correct output level is obtained, increase the input voltage to the desired level.

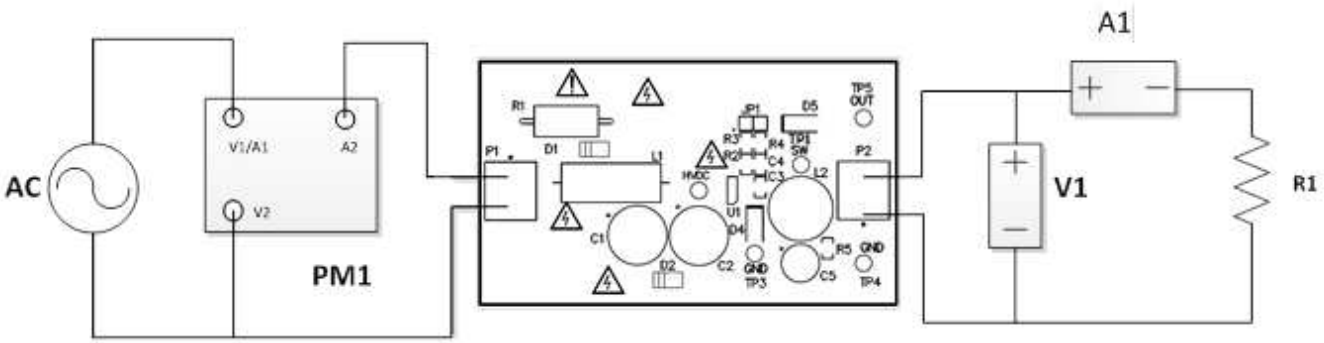

Figure 2. UCC28880EVM-616 Test Setup

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

Load: The UCC28880EVM-616 is capable of delivering 100 mA of output current. 50 Ω, at 1 W is the minimum value of load resistance for the 5-V output and 130 Ω at 5 W is the minimum value of load resistance for the 13-V output. Alternatively an electronic load may be used.

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: 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: Two digital multimeters are used to measure the regulated output voltage (DMM) and load current (DMM).

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.

9 Performance Data and Typical Characteristic Curves

9.1 Typical Efficiency and Load Regulation

Table 6. Efficiency and Regulation at 115 V_{AC} for 13-V Output

V_O	I_O	P_{IN}	EFFICIENCY
13.19	0	27	0.0
12.7	9	174	65.7
12.66	19	291	82.7
12.63	29	442	82.9
12.61	40	632	79.8
12.6	51	794	80.9
12.59	59	922	80.6
12.58	70	1091	80.7
12.57	79	1221	81.3
12.56	89	1390	80.4
12.57	100	1554	80.9

Table 7. Efficiency and Regulation at 230 V_{AC} for 13-V Output

V_O	I_O	P_{IN}	EFFICIENCY
13.23	0	38	0.0
12.71	9	184	62.2
12.67	19	294	81.9
12.63	30	492	77.0
12.61	41	648	79.8
12.6	51	815	78.8
12.59	61	986	77.9
12.58	69	1116	77.8
12.57	80	1284	78.3
12.57	91	1448	79.0
12.59	100	1523	82.7

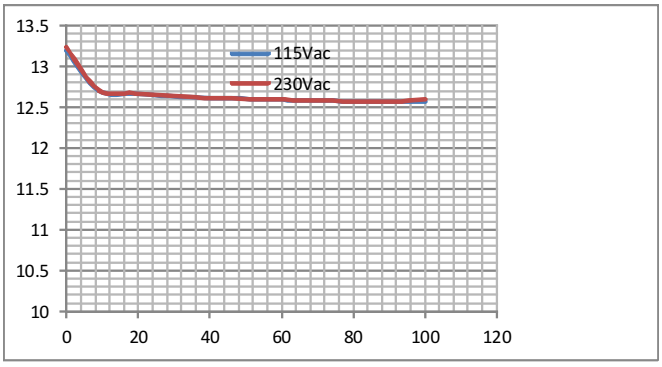

Figure 3. Regulation for 13-V Output

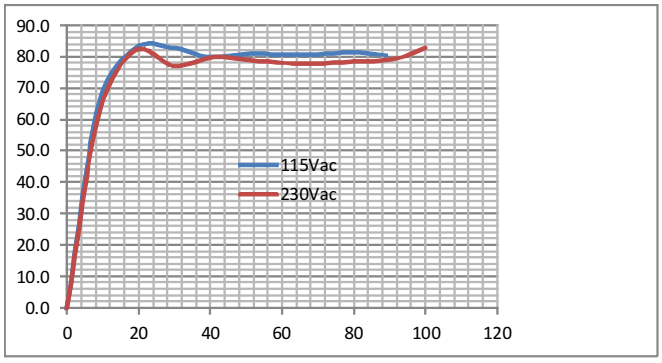

Figure 4. Efficiency for 13-V Output

Table 8. Efficiency and Regulation at 115 V_{AC} for 5-V Output

V_O	I_O	P_{IN}	EFFICIENCY
6.18	0	14	0.0
4.51	10	71	63.5
4.43	19	134	62.8
4.4	29	197	64.8
4.38	39	261	65.4
4.36	49	332	64.3
4.35	59	405	63.4
4.34	70	481	63.2
4.33	81	555	63.2
4.32	89	613	62.7
4.31	100	689	62.6

Table 9. Efficiency and Regulation at 230 V_{AC} for 5-V Output

V_O	I_O	P_{IN}	EFFICIENCY
6.26	0	24	0.0
4.51	10	81	55.7
4.44	19	140	60.3
4.4	29	214	59.6
4.38	39	275	62.1
4.37	49	344	62.2
4.36	60	418	62.6
4.35	70	492	61.9
4.34	78	549	61.7
4.34	89	625	61.8
4.33	100	703	61.6

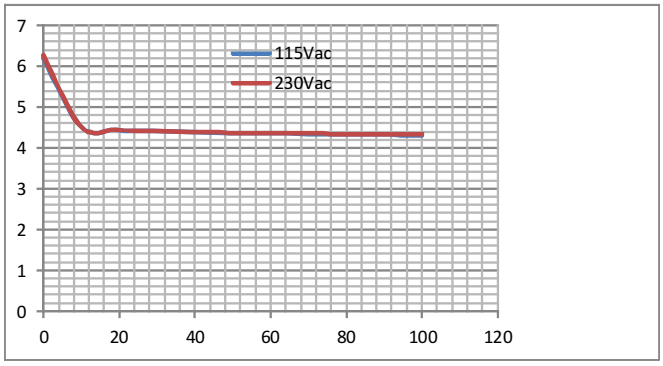

Figure 5. Regulation for 5-V output

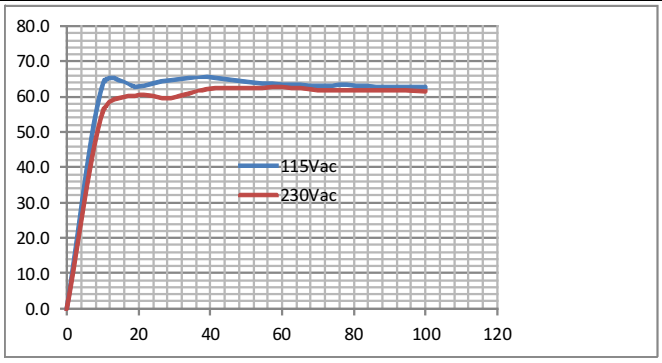

Figure 6. Efficiency for 5-V output

9.2 Output Ripple

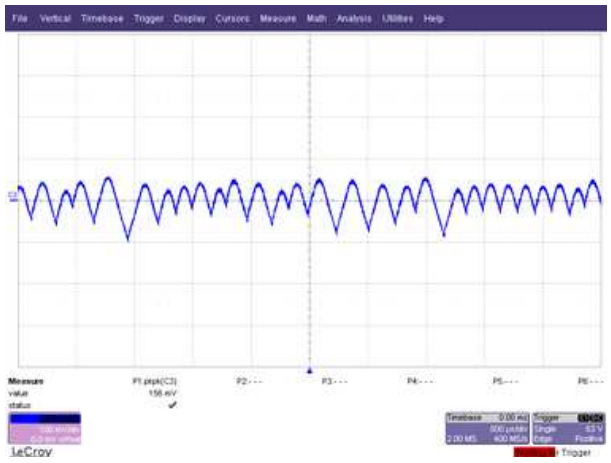

Figure 7. Output Ripple for 5-V Output

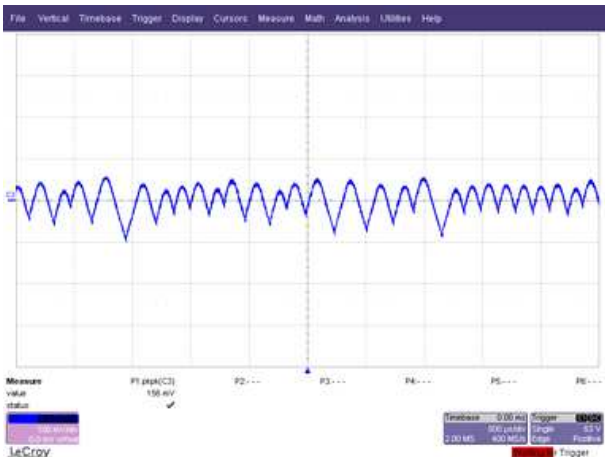

Figure 8. Output Ripple for 13-V Output

9.3 Switching Waveforms

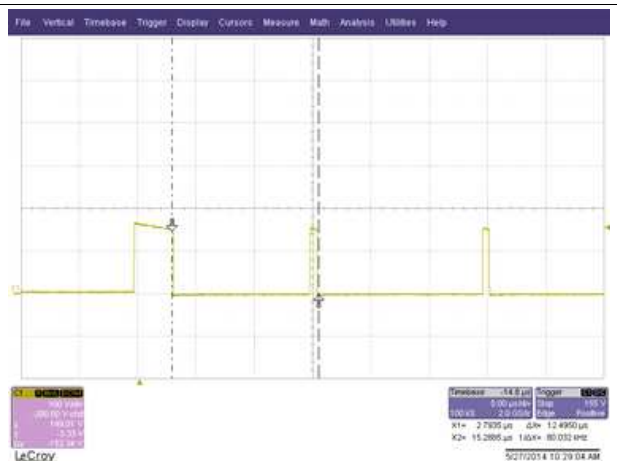

Figure 9. VD4 at 115 V_{AC} In, 4.27 V_{OUT}, 75 Ω

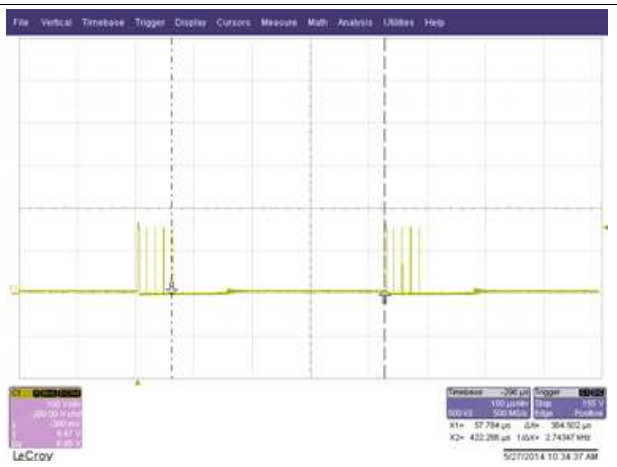

Figure 10. VD4 at 115 V_{AC} In, 4.27 V_{OUT}, 75 Ω

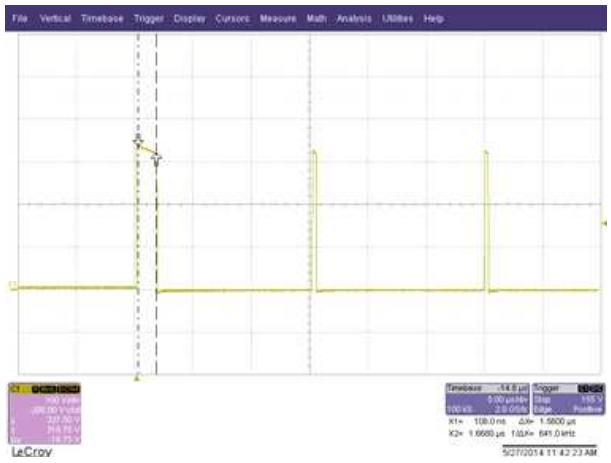

Figure 11. VD4 at 230 V_{AC} In, 4.27 V_{OUT}, 75 Ω

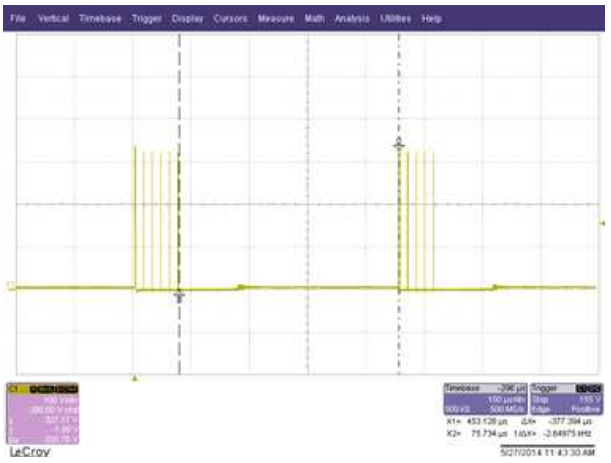

Figure 12. VD4 at 230 V_{AC} In, 4.27 V_{OUT}, 75 Ω

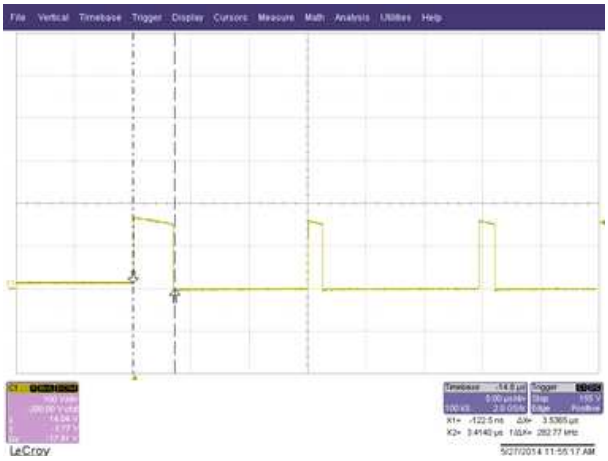

Figure 13. VD4 at 115 V_{AC} In, 12.55 V_{OUT}, 100 mA

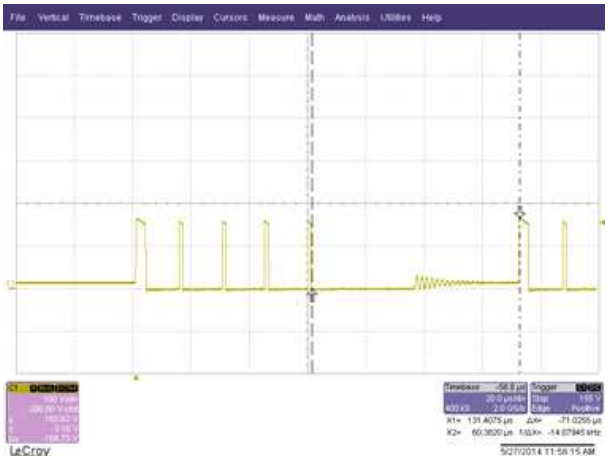

Figure 14. VD4 at 115 V_{AC} In, 12.55 V_{OUT}, 100 mA

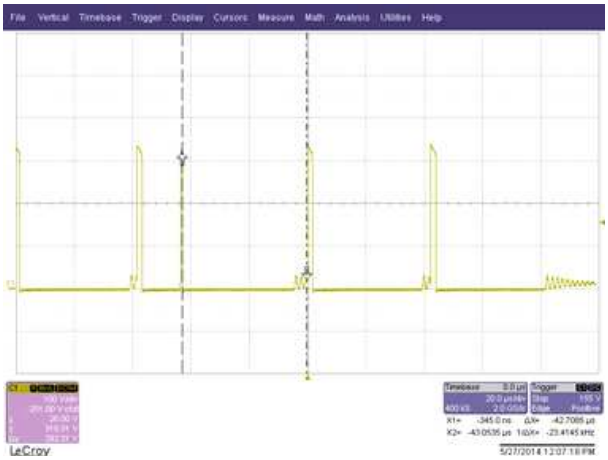

Figure 15. VD4 at 230 V_{AC} In, 12.55 V_{OUT}, 100 mA

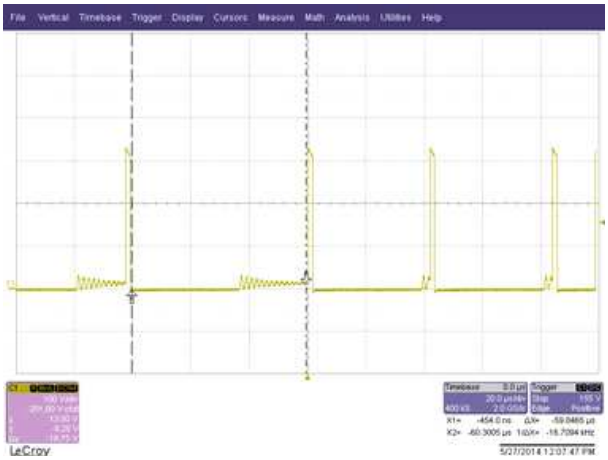

Figure 16. VD4 at 230 V_{AC} In, 12.60 V_{OUT}, 100 mA

9.4 EMI Test Data

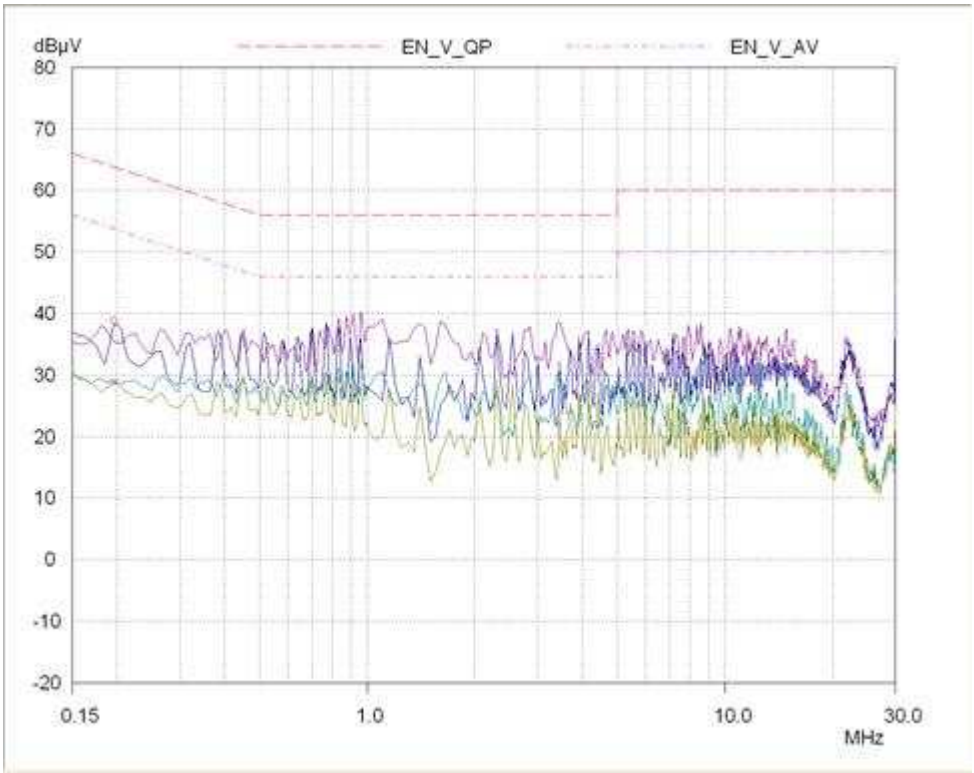

Figure 17. EMI, V_{IN} = 115 V_{RMS} and 230 V_{RMS}, Full Load

10 EVM Assembly Drawing and PCB Layout

Figure 18 and Figure 19 show the design of the UCC2880EVM-616 printed circuit board.

Figure 18. UCC28880EVM-616 Assembly (top view)

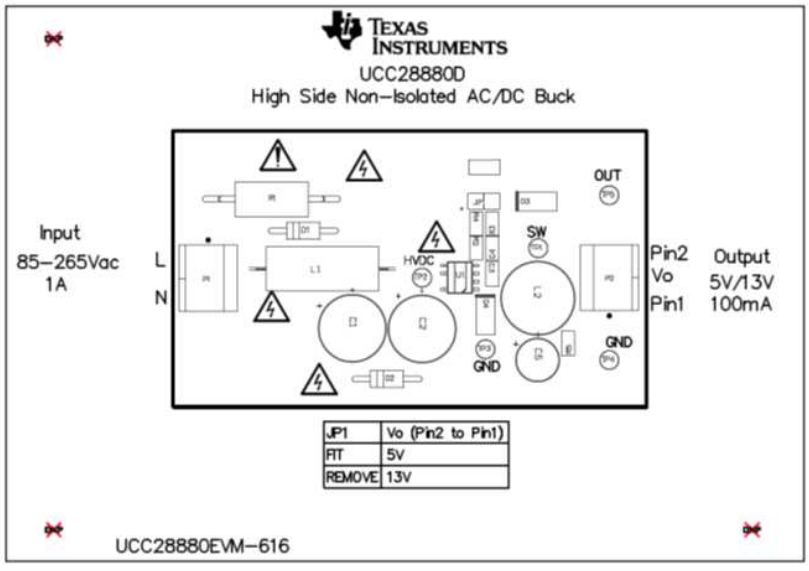

Figure 19. UCC28880EVM-616 Layout (top layer)

11 List of Materials

Table 10. UCC28880EVM-616 List of Materials

QTY	DES	DESCRIPTION	MANUFACTURER	PART NUMBER
1	PCB	Printed Circuit Board	Any	PWR616
2	C1, C2	Capacitor, aluminum, 4.7 µF, 450 V, ±20%, TH	Kemet	ESH475M450AH2AA
1	C3	Capacitor, ceramic, 0.1 µF, 50 V, ±10%, X7R, 0805	Kemet	C0805C104K5RACTU
1	C4	Capacitor, ceramic, 1 µF, 50 V, ±10%, X7R, 0805	MuRata	GRM21BR71H105KA 12L
1	C5	Capacitor, aluminum, 100 µF, 25 V, ±20%, 0.13 Ω, TH	Panasonic	EEU-FM1E101
2	D1, D2	Diode, P-N, 1000 V, 1 A, TH	Fairchild Semiconductor	1N4007
2	D3, D4	Diode, Ultrafast, 600 V, 1 A, SMA	ST Microelectronics	STTH1R06A
4	H1, H2, H3, H4	Bumpon, hemisphere, 0.44 X 0.20, clear	3M	SJ-5303 (CLEAR)
1	JP1	Header, TH, 100 millimeter, 2 x 1, gold plated, 230 millimeter above insulator	Samtec	TSW-102-07-G-S
1	L1	Inductor, wirewound, ferrite, 1 mH, 0.2A, 2.3 Ω, TH	Bourns	5800-102-RC
1	L2	Inductor, wirewound, 2.2 mH, 0.33A, 3.2 Ω, TH	TDK	TSL1112RA-222JR33-PF
2	P1, P2	Terminal block, 2 x 1, 5.08 mm, TH	TE Connectivity	282841-2
1	R1	Resistor, 8.2 Ω, 5%, 3 W, fusible, TH	Bourns	PWR4522AS8R20JA
1	R2	Resistor, 10.0 kΩ, 1%, 0.125 W, 0805	Panasonic	ERJ-6ENF1002V
1	R3	Resistor, 121 kΩ, 1%, 0.125 W, 0805	Panasonic	ERJ-6ENF1213V
1	R4	Resistor, 57.6 kΩ, 1%, 0.125 W, 0805	Panasonic	ERJ-6ENF5762V
1	R5	Resistor, 12.1 kΩ, 1%, 0.125 W, 0805	Panasonic	ERJ-6ENF1212V
1	SH-JP1	Shunt, 100 millimeter, flash gold, black	Sullins Connector Solutions	SPC02SYAN
2	TP1, TP2	Test point, miniature, red, TH	Keystone	5000
2	TP3, TP4	Test point, miniature, black, TH	Keystone	5001
1	TP5	Test point, miniature, white, TH	Keystone	5002
1	U1	Low Quiescent Current Switcher Device for AC-to-DC Power Supplies, D0007A	Texas Instruments	UCC28880D

Revision History

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

Changes from B Revision (January 2017) to C Revision **Page**

- Changed table 7 title from "Efficiency and Regulation at 115 V_{AC} for 13-V Output" to "Efficiency and Regulation at 230 V_{AC} for 13-V Output" 11

Changes from A Revision (August 2014) to B Revision **Page**

- Added EMI Test Data image. 15

Changes from Original (July 2014) to A Revision **Page**

- Added an updated UCC28880EVM-616 description. 2
- Added Preset Output Voltage of ~13 V feature description. 3
- Added UCC28880EVM-616 circuit description. 8

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.

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*

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 to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

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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.

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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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