UCC28064EVM-004 300-W Interleaved PFC Pre-Regulator

The UCC28064A is a dual-phase, transition-mode Power Factor Correction (PFC) pre-regulator. The UCC28064EVM-004 is an evaluation module (EVM) with a 390-V, 300-W, dc output that operates from a universal input of 85 V_{RMS} to 265 V_{RMS} and provides power-factor correction.

Throughout this document, the acronym *EVM* and the phrases *evaluation board* and *evaluation module* are synonymous with the UCC28064EVM.

Trademarks

Natural Interleaving is a trademark of Texas Instruments.

1 Description

The pre-regulator uses *UCC28064A PFC Interleaved Controller* to shape the input current wave to provide power-factor correction. This device uses TI's *Natural Interleaving* ™ technology to interleave boost phases.

This user's guide provides the schematic, List of Materials, assembly drawing for a single-sided printed circuit board application, and test set-up information necessary to evaluate the UCC28064A in a typical PFC application.

2 Thermal Requirements

This evaluation module will operate up to 300 W without external cooling in ambient temperatures of 25°C.

3 Electrical Characteristics

Table 1 summarizes the electrical specifications of the UCC28064EVM-004.

Table 1. UCC28064EVM-004 Electrical Specifications

PARAMETER	CONDITIONS	UCC28064EVM			UNITS
		MIN	TYP	MAX	
RMS input voltage (ac line)		85		265	V_{RMS}
Output voltage, V_{OUT}			390		V
Line frequency		47		63	Hz
Power factor (PF) at maximum load		0.9			
Output power				300	W
Full load efficiency	AC line = 115 V		93%		
	AC line = 230 V		96%		

4 Schematics

Figure 1 shows the schematic for this EVM. See Table 1 for specific values

To evaluate inductor ripple currents, resistors R25 and R26 can be removed and replaced with current loops.

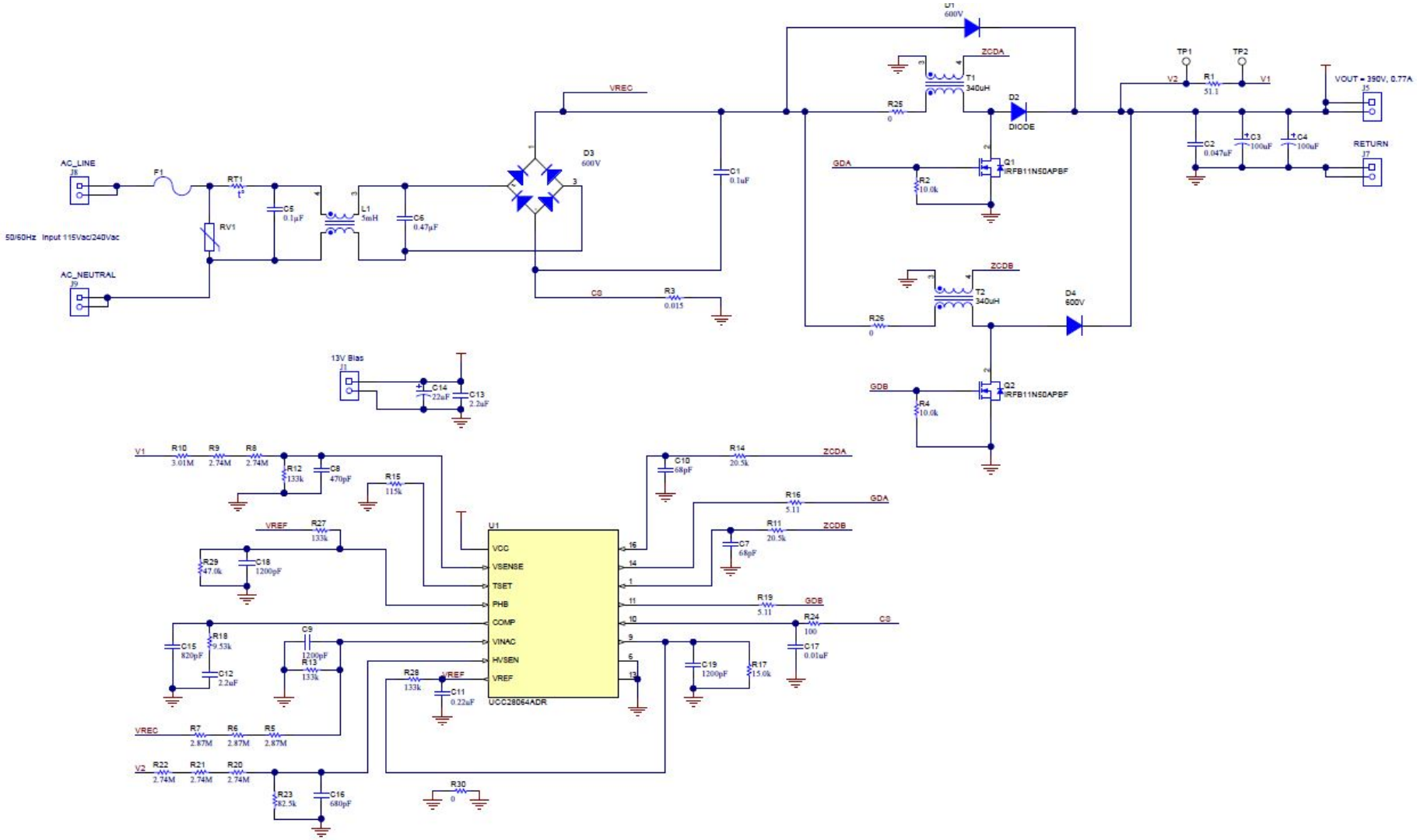


Figure 1. UCC28064EVM-004 Schematic Diagram

5 Test Setup and Power-Up/Power-Down Instructions

WARNING

There are high voltages present on the pre-regulator. It must only be handled by experienced power supply professionals. To evaluate this board as safely as possible, the following test configuration must be used:

- Connect an isolation transformer between the source and unit
- Attach a voltmeter and a resistive or electronic load to the unit output **before** supplying power to the EVM.

A separate 13-V bias supply is required to power the UCC28064A control circuitry. The unit will start up under no-load conditions. However, for safety, a load must be connected to the output of the device before it is powered up. The unit must also never be handled while power is applied to it or when the output voltage is above 50-V dc. Refer to Figure 2 for a recommended test setup diagram.

CAUTION

There are very high voltages on the board. Components can and will reach temperatures greater than 100°C. Use caution when handling the EVM.

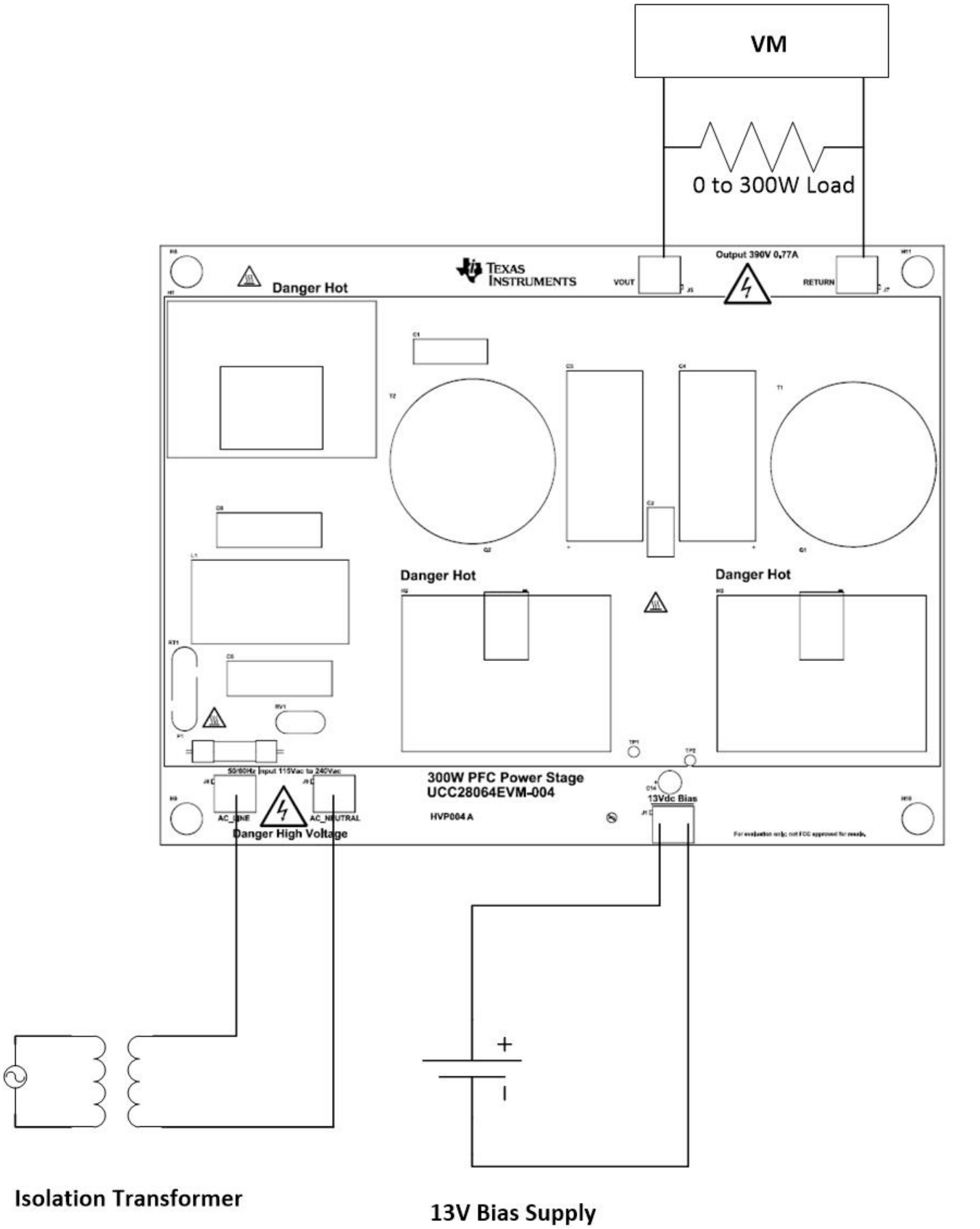


Figure 2. Test Setup

6 Typical Performance Data

Figure 3 through Figure 14 present characteristic performance data for the UCC28064EVM-004.

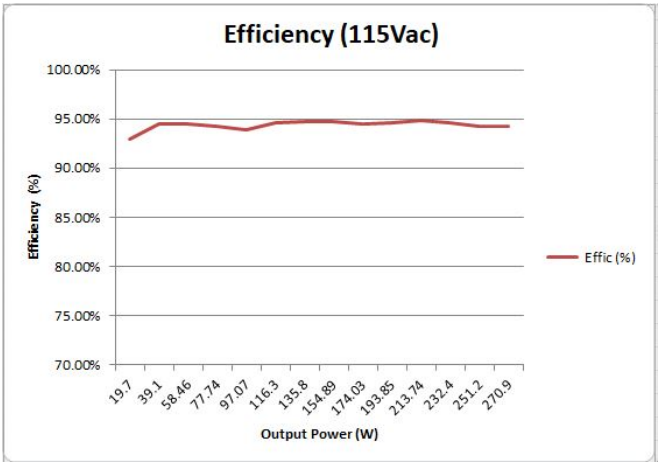


Figure 3. Efficiency at 115 V_{RMS}

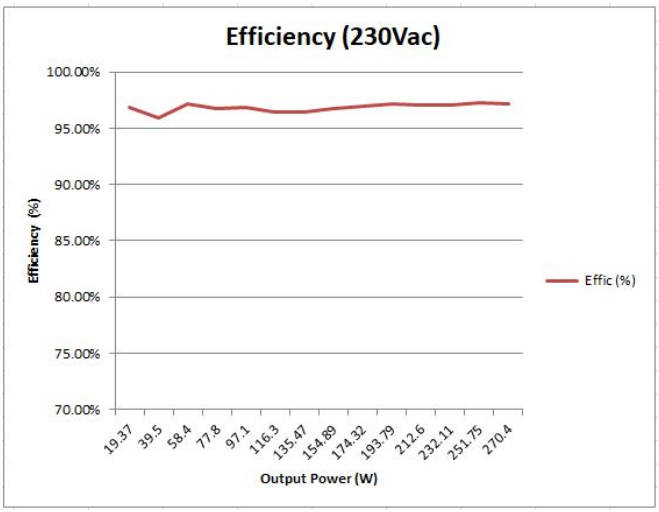


Figure 4. Efficiency at 230 V_{RMS}

Table 2. Performance Data at 115Vac

Pin (W)	Power Factor	Vo (V)	Io (A)	Pout (W)	Effic (%)	THD (%)
.055		388	0			
21.2	0.953	387.8	0.05	19.7	92.92	25.43
41.4	0.985	387.10	0.1	39.1	94.44	4.54
61.83	0.993	386.96	0.15	58.46	94.55	3.19
82.43	0.995	387.15	0.2	77.74	94.31	2.82
103.44	0.997	387.05	0.25	97.07	93.84	7.72
122.9	0.995	386.63	0.3	116.3	94.63	3.31
143.3	0.996	386.54	0.35	135.8	94.77	3.04
163.5	0.997	387.09	0.4	154.89	94.73	2.82
184.1	0.997	386.3	0.45	174.03	94.53	2.49
205	0.998	386.21	0.5	193.85	94.56	2.33
225.4	0.998	386.17	0.55	213.74	94.83	2.28
245.7	0.998	386.4	0.6	232.4	94.59	1.92
266.4	0.998	387.2	0.65	251.2	94.29	2.18
287.4	0.999	386.2	0.7	270.9	94.26	1.98

Table 3. Performance Data at 230Vac

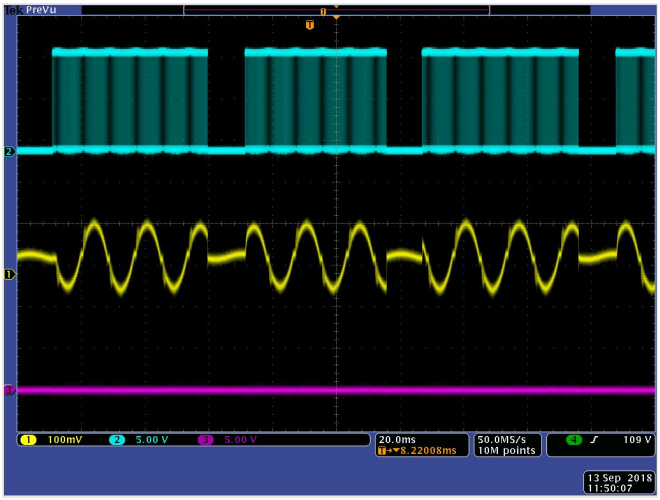
Pin (W)	Power Factor	Vo (V)	Io (A)	Pout (W)	Effic (%)	THD (%)
.075		388	0			
20	0.829	388.45	0.05	19.37	96.85	38.4
41.16	0.935	386.7	0.1	39.5	95.97	29.08
60.12	0.958	386.88	0.15	58.4	97.14	18.88
80.4	0.975	386.78	0.2	77.8	96.77	14.03
100.21	0.982	386.52	0.25	97.1	96.90	11.72
120.6	0.977	386.81	0.3	116.3	96.43	18.55
140.51	0.982	386.74	0.35	135.47	96.41	15.97

Table 3. Performance Data at 230Vac (continued)

Pin (W)	Power Factor	Vo (V)	Io (A)	Pout (W)	Effic (%)	THD (%)
160.1	0.986	386.12	0.4	154.89	96.75	14.45
179.74	0.988	386.28	0.45	174.32	96.98	12.94
199.48	0.99	386.39	0.5	193.79	97.15	11.82
219.15	0.991	386.81	0.55	212.6	97.01	10.84
239.04	0.993	386.89	0.6	232.11	97.10	9.89
258.7	0.993	386.53	0.65	251.75	97.31	9.26
278.44	0.994	387.03	0.7	270.4	97.11	8.64

6.1 Burst Mode Operation

Figure 5 and Figure 6 illustrate burst mode line current at 115Vac and 230Vac



C2: GDA, C3: GDB, C1: I_{LINE}

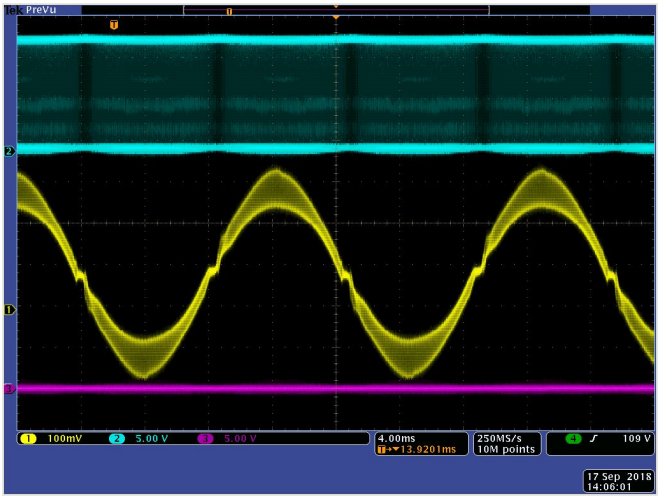
Figure 5. 115Vac 20W

C2: GDA, C3: GDB, C1: I_{LINE}

Figure 6. 230Vac 20W

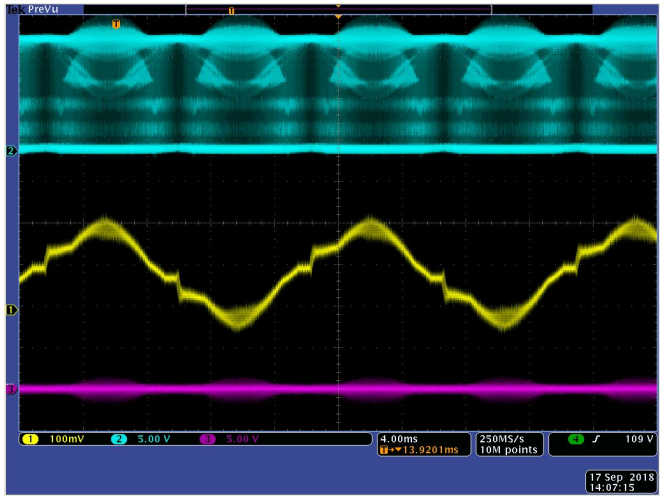
6.2 Single Phase Operation

Figure 7 and Figure 8 show the input line current, gate drive signals GDA and GDB in the single phase mode .



C2: GDA, C3: GDB, C1: I_{LINE}

Figure 7. 115Vac 80W

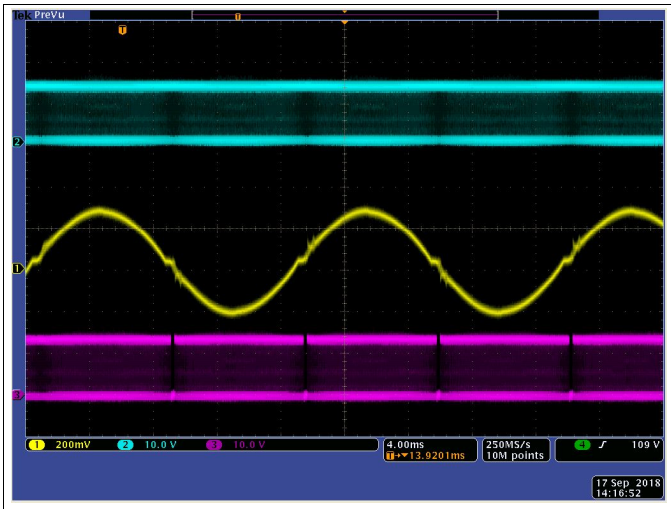


C2: GDA, C3: GDB, C1: I_{LIN}

Figure 8. 230Vac 80W

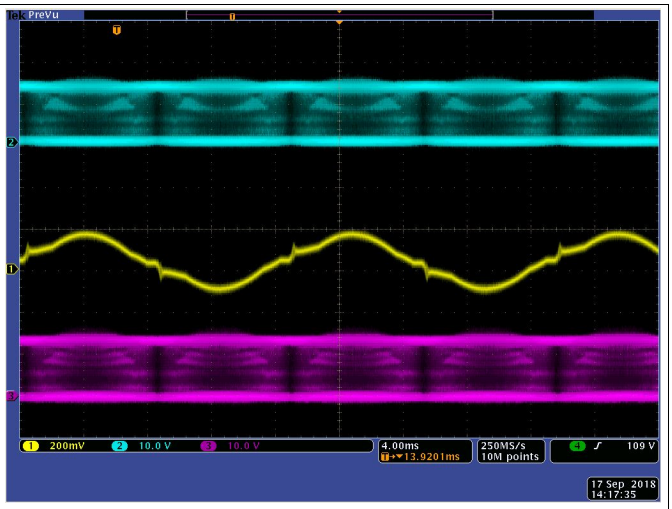
6.3 Dual Phase (Interleaved) Operation

Figure 9 and Figure 10 show the input line current, gate drive signals GDA and GDB in the dual phase (or interleaved) mode phase mode



C2: GDA, C3: GDB, C1: I_{LINE}

Figure 9. 115V 200W

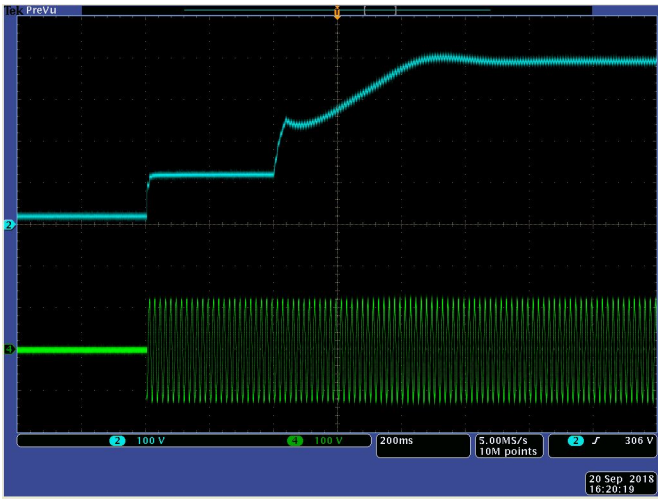


C2: GDA, C3: GDB, C1: I_{LINE}

Figure 10. 230V 200W

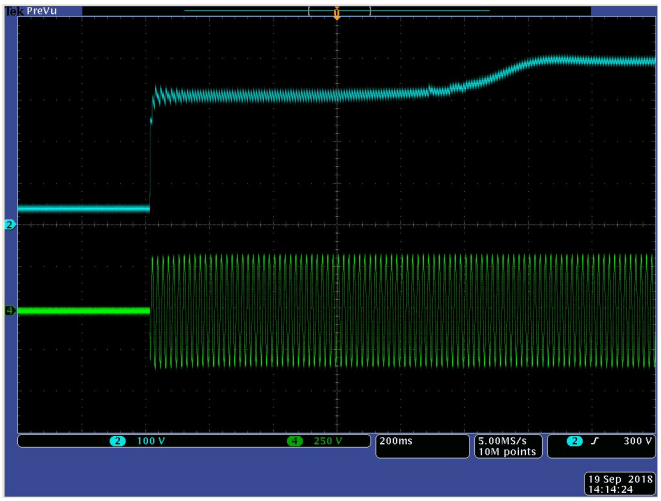
6.4 Startup Characteristics

Figure 11 and Figure 12 show the startup behaviour at 85Vac and 264Vac



C2: V_{out} , C4: V_{ACin}

Figure 11. Startup 85Vac 200W



C2: V_{out} , C4: V_{ACin}

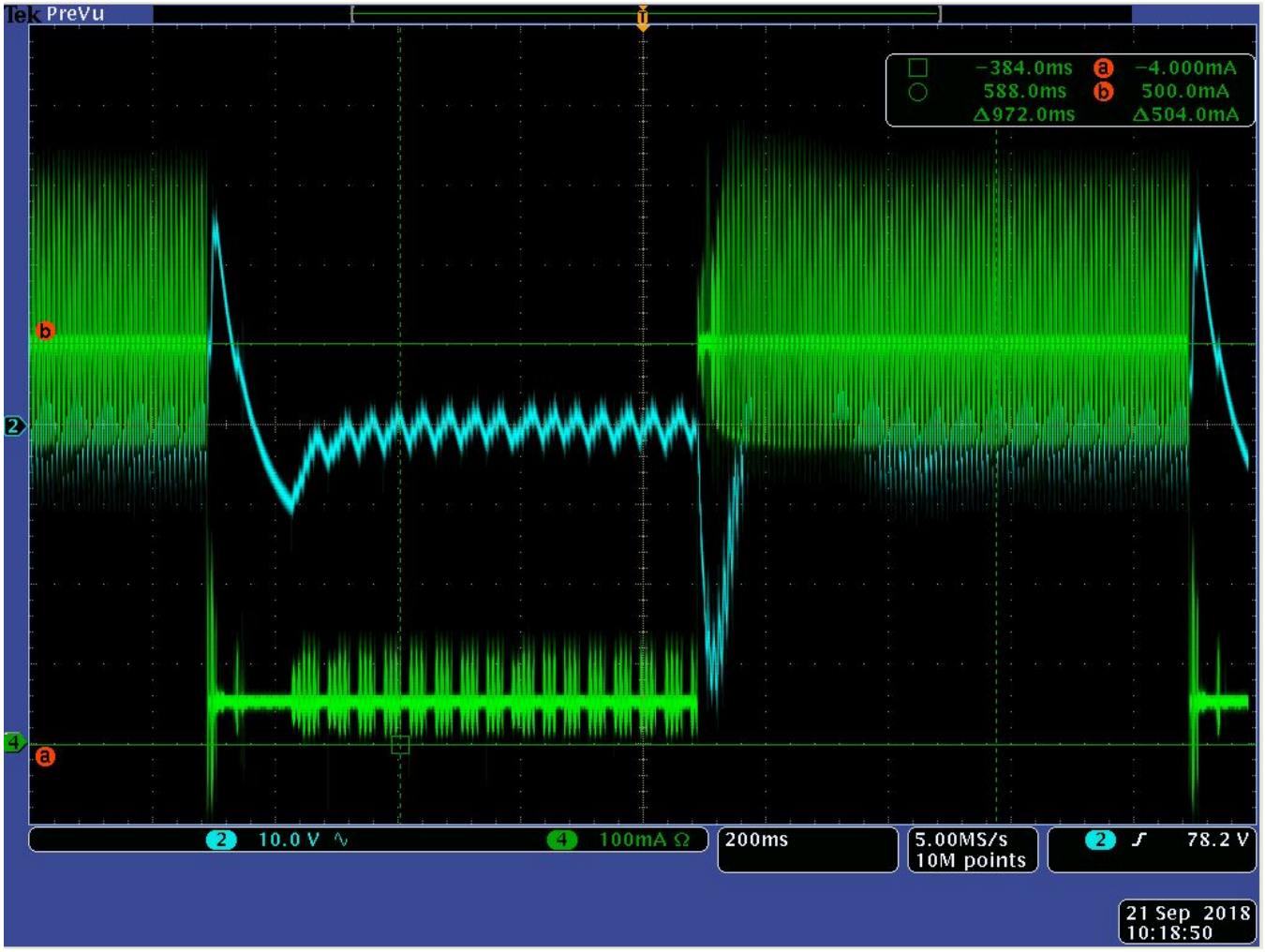
Figure 12. Startup 264Vac 200W

6.5 Load Step

A load transient test was conducted with an ac source on the EVM. The load was varied from 50mA to 500mA to 50mA.

This corresponds to a 20W to 200W to 20W variation.

The results are detailed in Figure 13.



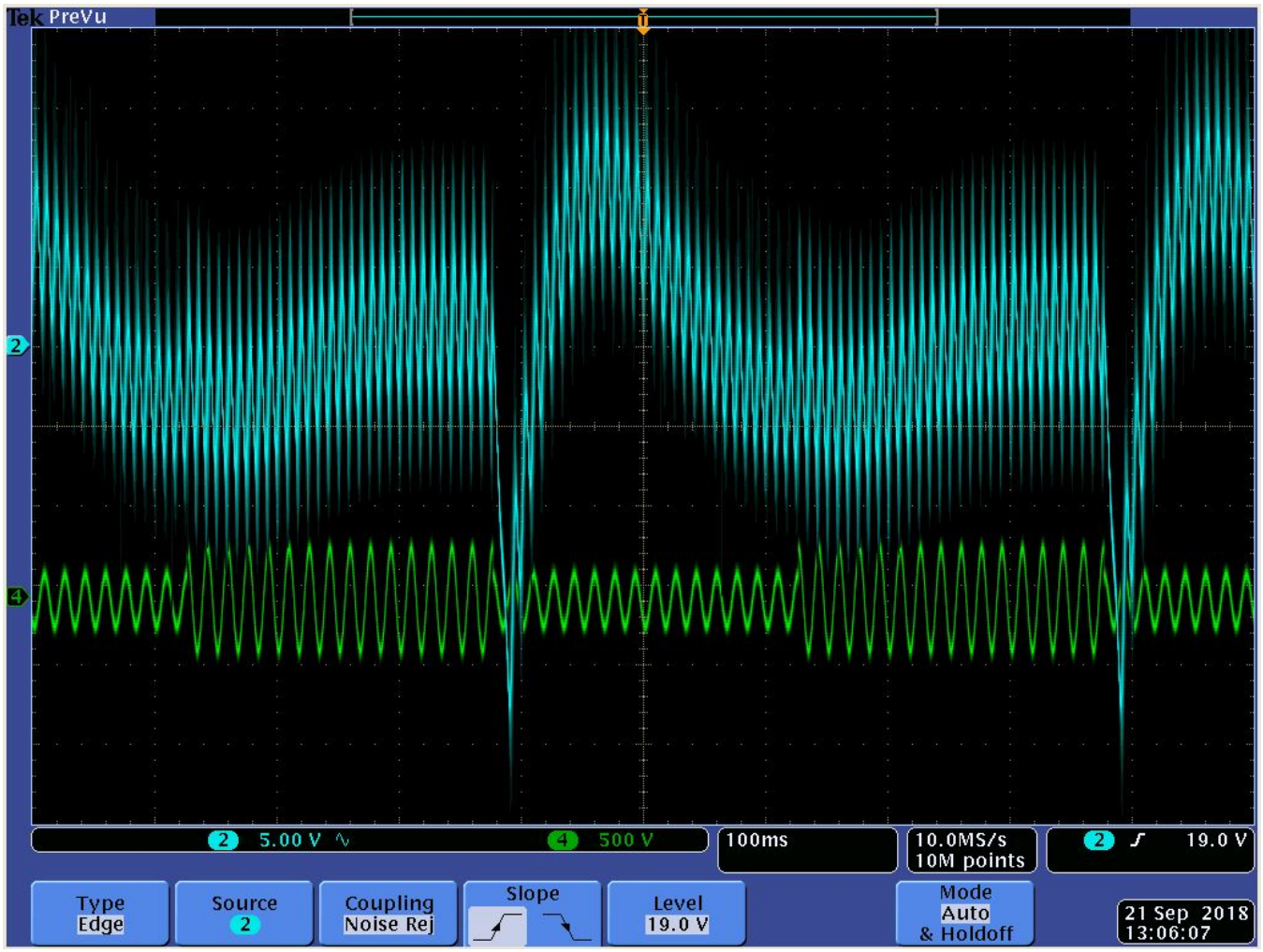
C2: V_{out} , C4: I_{OUT}

Figure 13. Load Step

7 Line Transient

A line transient test was conducted with an ac source on the EVM. The load was fixed at 200W and the line was varied from 115Vac to 230Vac

The results are detailed in to UCC28064A line step data Figure 14



C2: V_{out} , C4: V_{inAC}

Figure 14. Line Step

8 Reference Design Assembly Drawing

Figure 15 to Figure 18 show the top and bottom layers (respectively) of the UCC28064EVM-004 printed circuit board

NOTE: Board layouts are not to scale. These figures are intended to show how the board is laid out; they are not intended to be used for manufacturing UCC28064EVM-004 PCBs.

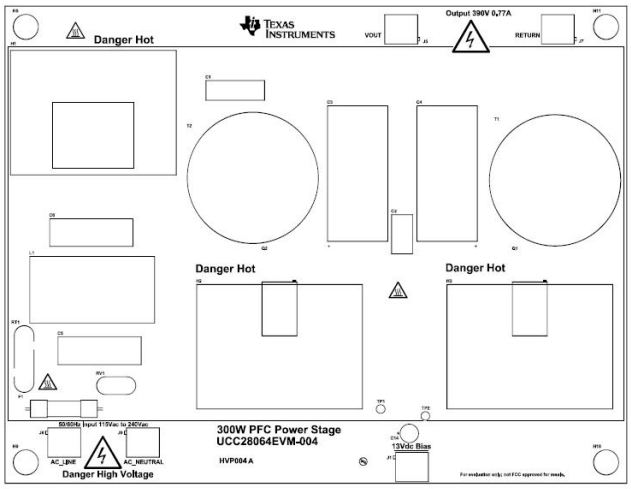


Figure 15. Top Layer Assembly

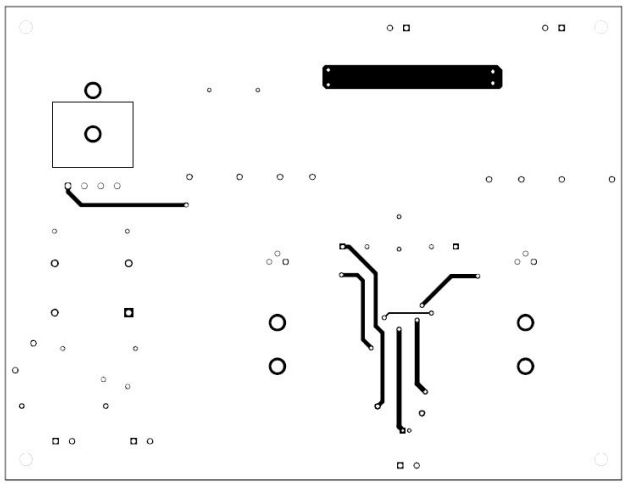


Figure 16. Top Layer Copper

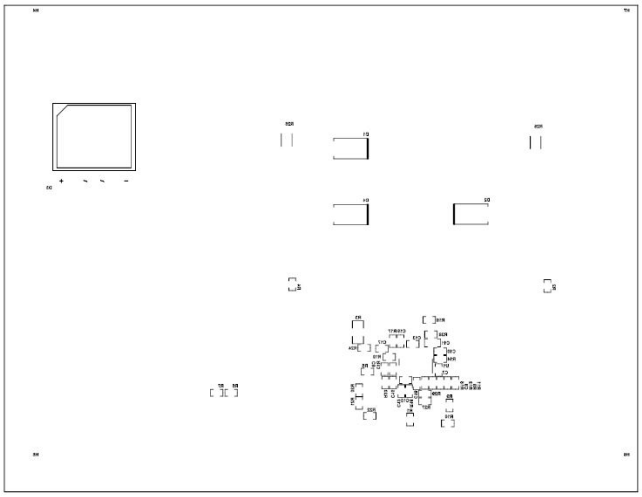


Figure 17. Bottom Layer Assembly

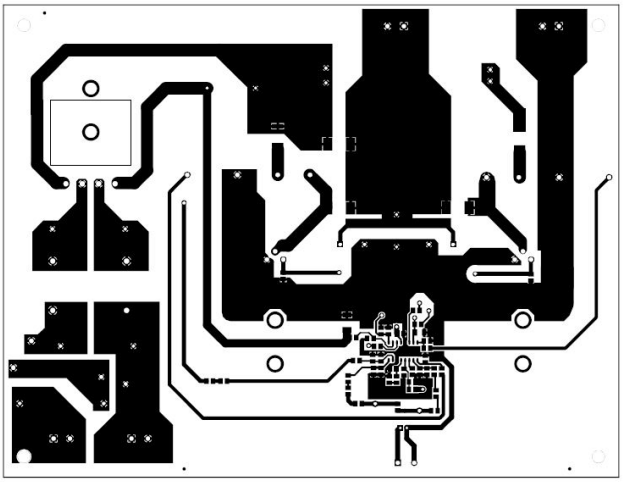


Figure 18. Bottom Layer Copper

9 List of Materials

Table 4 below lists the EVM components as configured according to the schematics

Table 4. List of Materials

Designator	Qty	Description	PartNumber	Manufacturer
PCB	1	Printed Circuit Board	HVP004	Any
C1	1	CAP, Film, 0.1 µF, 275 V,+/- 20%, TH	ECQ-U2A104ML	Panasonic
C2	1	CAP, Film, 0.047 µF, 630 V,+/- 10%, TH	ECQ-E6473KF	Panasonic
C3, C4	2	CAP, AL, 100 µF, 450 V, +/- 20%, TH	EKXG451ELL101MM40S	Chemi-Con
C5, C6	2	CAP, Film, 0.47 µF, 275 V,+/- 20%, TH	ECQ-U2A474ML	Panasonic
C7, C10	2	CAP, CERM, 68 pF, 50 V,+/- 5%, C0G/NP0, 0805	08055A680JAT2A	AVX
C8	1	CAP, CERM, 470 pF, 25 V, +/- 10%, X7R, 0805	GRM216R71E471KA01D	MuRata
C9, C18, C19	3	CAP, CERM, 1200 pF, 25 V,+/- 10%, X7R, 0805	GRM216R71E122KA01D	MuRata
C11	1	CAP, CERM, 0.22 µF, 50 V,+/- 10%, X7R, 1206	GRM31MR71H224KA01L	MuRata
C12, C13	2	CAP, CERM, 2.2 µF, 50 V, +/- 10%, X7R, 0805	C2012X7R1H225K125AC	TDK
C14	1	CAP, AL, 22 µF, 35 V, +/- 20%, TH	ECA-1VM220	Panasonic
C15	1	CAP, CERM, 820 pF, 25 V, +/- 10%, X7R, 0805	GRM216R71E821KA01D	MuRata
C16	1	CAP, CERM, 680 pF, 25 V,+/- 10%, X7R, 0805	8.85012E+11	Wurth Elektronik
C17	1	CAP, CERM, 0.01 µF, 50 V, +/- 5%, X7R, 0805	08055C103JAT2A	AVX
D1, D2, D4	3	Diode, Ultrafast, 600 V, 3 A, SMC	MURS360T3G	ON Semiconductor
D3	1	Diode, Switching-Bridge, 600 V, 6 A, TH	GBU6J	Fairchild Semiconductor
F1	1	Fuse, 8 A, 250VAC/VDC, TH	0216008.MXESPP	Littelfuse
H1, H2, H3	3	Heatsink, TO-220, Black Anodized	7-345-2PP-BA	CTS Electrocomponents
H4, H5, H6, H7	4	Standoff, Hex, 0.5"L #6-32 Nylon	1903C	Keystone
H8, H9, H10, H11	4	HEX STANDOFF 6-32 NYLON 1-1/2"	4824	Keystone
H12, H13, H14, H15, H16, H17	6	MACHINE SCREW PAN SLOTTED M3	29344	Keystone Electronics
H18, H19, H20, H21, H22, H23	6	M3 Kwik Nut 0.276" (7.01mm) Nylon	KNF-30	Essentra Components
H36	1	Thermal Grease for D3. Apply as needed.	120-2	Wakefield-Vette
H37, H38	2	THERMAL PAD SILICON	SP400-0.007-00-51	Bergquist
J1, J5, J7, J8, J9	5	Terminal Block, 5.08 mm, 2x1, Brass, TH	ED120/2DS	On-Shore Technology
L1	1	Coupled inductor, 5 mH, 8.9 A, 0.022 ohm, TH	8113-RC	Bourns
Q1, Q2	2	MOSFET, N-CH, 500 V, 11 A, AEC-Q101, TO-220AB	IRFB11N50APBF	Vishay-Siliconix
R1	1	RES, 51.1, 0.1%, 0.125 W, 0805	RT0805BRD0751R1L	Yageo America
R2, R4	2	RES, 10.0 k, 1%, 0.125 W, 0805	CRCW080510K0FKEA	Vishay-Dale
R3	1	RES, 0.015, 1%, 0.5 W, 2010	WSL2010R0150FEA	Vishay-Dale
R5, R6, R7	3	RES, 2.87 M, 1%, 0.125 W, 0805	CRCW08052M87FKEA	Vishay-Dale
R8, R9, R20, R21, R22	5	RES, 2.74 M, 1%, 0.125 W, 0805	CRCW08052M74FKEA	Vishay-Dale

Table 4. List of Materials (continued)

Designator	Qty	Description	PartNumber	Manufacturer
R10	1	RES, 3.01 M, 1%, 0.125 W, 0805	CRCW08053M01FKEA	Vishay-Dale
R11, R14	2	RES, 20.5 k, 1%, 0.125 W, 0805	CRCW080520K5FKEA	Vishay-Dale
R12, R13, R27, R28	4	RES, 133 k, 1%, 0.125 W, 0805	CRCW0805133KFKEA	Vishay-Dale
R15	1	RES, 115 k, 1%, 0.125 W, 0805	CRCW0805115KFKEA	Vishay-Dale
R16, R19	2	RES, 5.11, 1%, 0.125 W, 0805	CRCW08055R11FKEA	Vishay-Dale
R17	1	RES, 15.0 k, 1%, 0.125 W, 0805	CRCW080515K0FKEA	Vishay-Dale
R18	1	RES, 9.53 k, 1%, 0.125 W, 0805	ERJ-6ENF9531V	Panasonic
R23	1	RES, 82.5 k, 1%, 0.125 W, 0805	CRCW080582K5FKEA	Vishay-Dale
R24	1	RES, 100, 1%, 0.125 W, 0805	CRCW0805100RFKEA	Vishay-Dale
R25, R26	2	RES, 0, 5%, 1 W, AEC-Q200 Grade 0, 2512	CRCW25120000Z0EG	Vishay-Dale
R29	1	RES, 47.0 k, 1%, 0.125 W, 0805	ERJ-6ENF4702V	Panasonic
RT1	1	Thermistor NTC, 5 ohm, 25%, Disc, 220x770 mil	CL-40	GE Sensing
RV1	1	Varistor 275V RMS 10MM Radial, TH	S10K275E2	TDK
T1, T2	2	Inductor, 340 uH	CTX16-17769-R	Eaton
TP1, TP2	2	Test Point, Miniature, White, TH	5002	Keystone
U1	1	Natural Interleaving Transition Mode PFC Controller with Improved Light Load Efficiency, D0016A (SOIC-16)	UCC28064ADR	Texas Instruments

Revision History

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

Changes from Original (November 2017) to A Revision **Page**

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 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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