UCC28063EVM-723 300-W Interleaved PFC Pre-Regulator

The UCC28063 is a dual-phase, transition-mode Power Factor Correction (PFC) pre-regulator. The UCC28063EVM-723 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 UCC28063EVM.

1 Description

The pre-regulator uses the UCC28063 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 UCC28063 in a typical PFC application.

2 Thermal Requirements

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

3 Electrical Characteristics

Table 1 summarizes the electrical specifications of the UCC28063EVM-723.

Table 1. UCC28063EVM-723 Electrical Specifications

PARAMETER	CONDITIONS	UCC28063EVM			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		94%		
	AC line = 230 V		97%		

Natural Interleaving is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

4 Schematics

Figure 1 and Figure 2 show the schematics for this EVM. See the List of Materials for specific values.

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

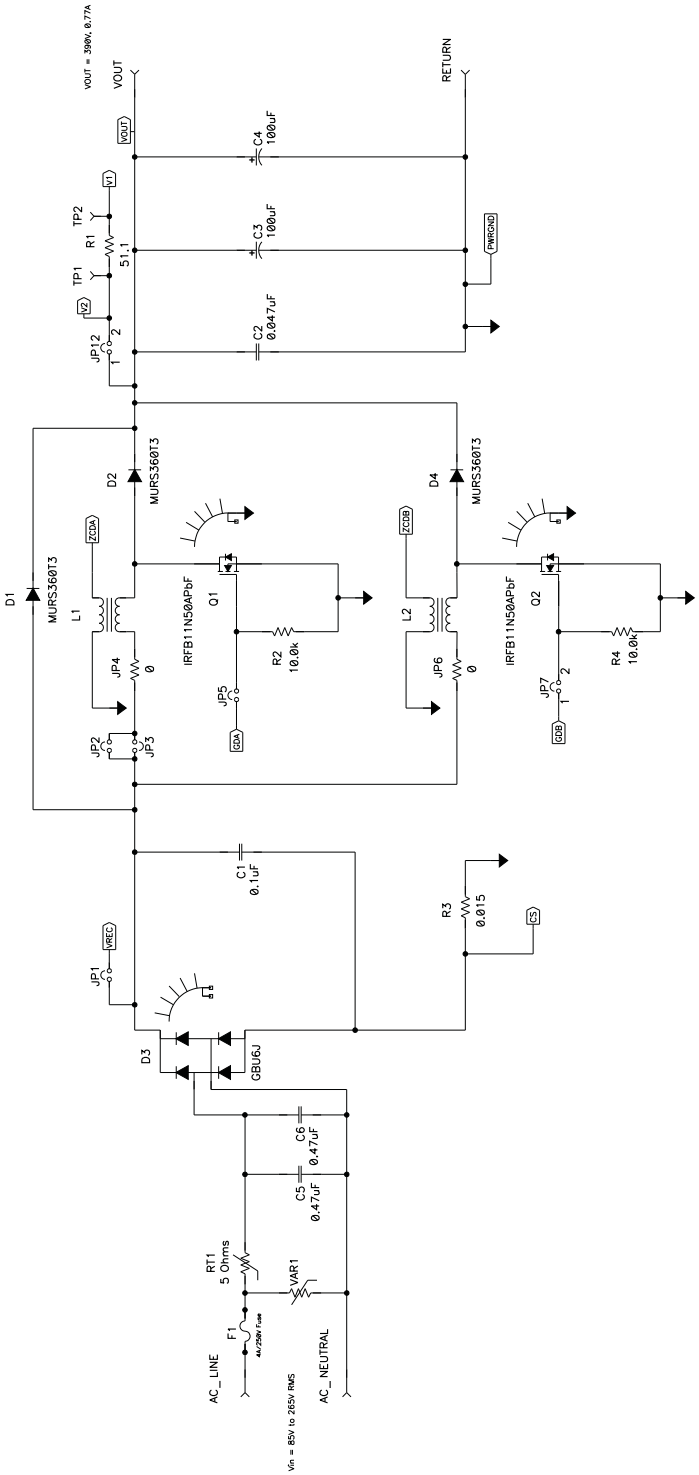

Figure 1. Interleaved PFC Power Stage

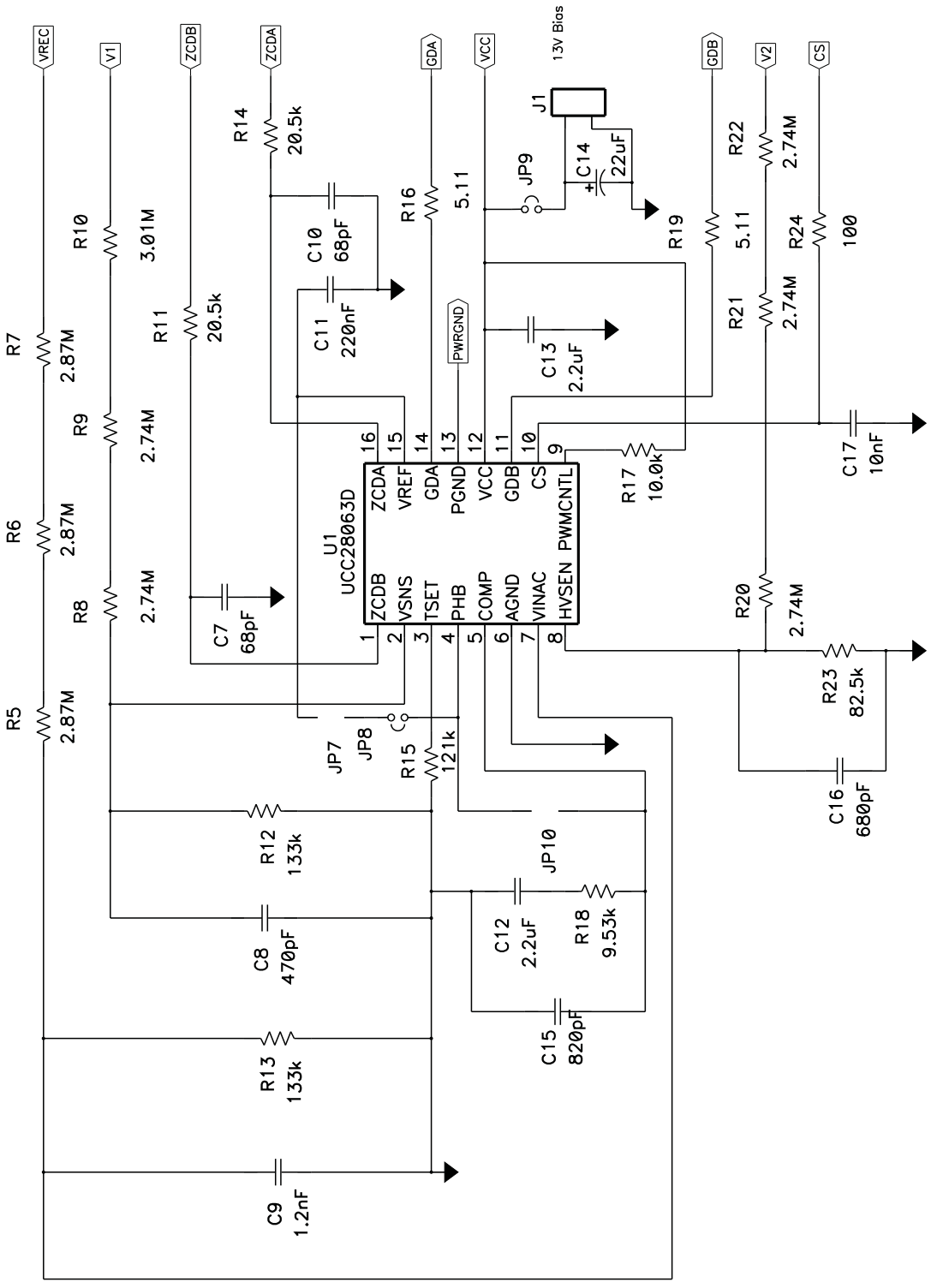

Figure 2. Controller Circuitry

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

WARNING

There are high voltages present on the pre-regulator. It should only be handled by experienced power supply professionals. To evaluate this board as safely as possible, the following test configuration should 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 UCC28063 control circuitry. The unit will start up under no-load conditions. However, for safety, a load should be connected to the output of the device before it is powered up. The unit should also never be handled while power is applied to it or when the output voltage is above 50-V dc. Refer to Figure 3 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.

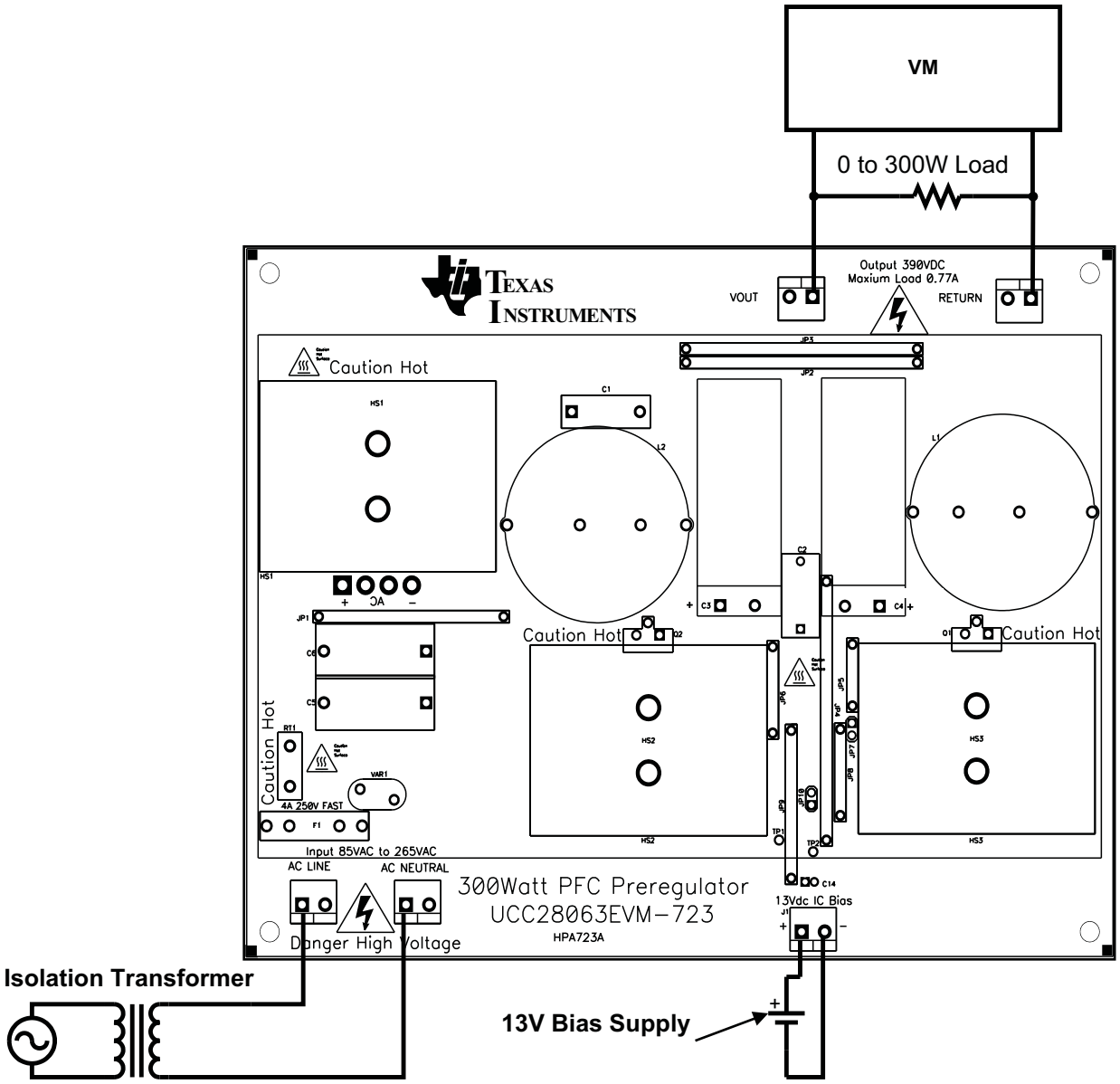

Figure 3. Test Setup

6 Typical Performance Data

Figure 4 through Figure 7 present characteristic performance data for the UCC28063EVM-723.

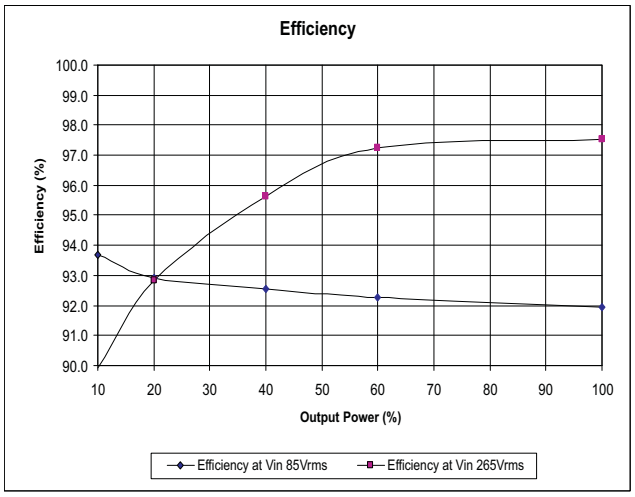

Figure 4. Efficiency at 85 V_{RMS} and 265 V_{RMS}

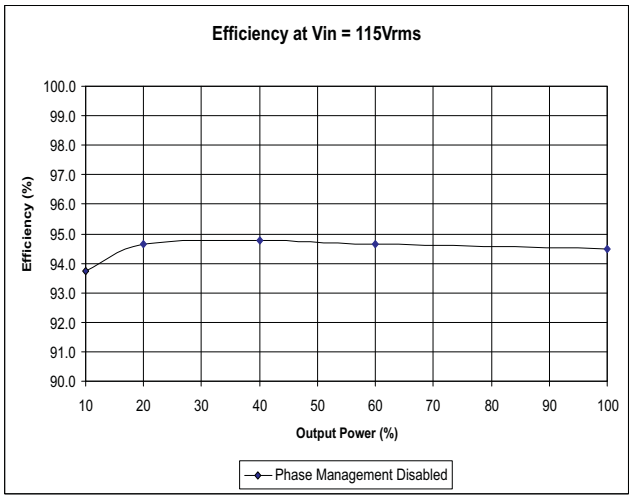

Figure 5. Efficiency at 115 V_{RMS}, Without Phase Management

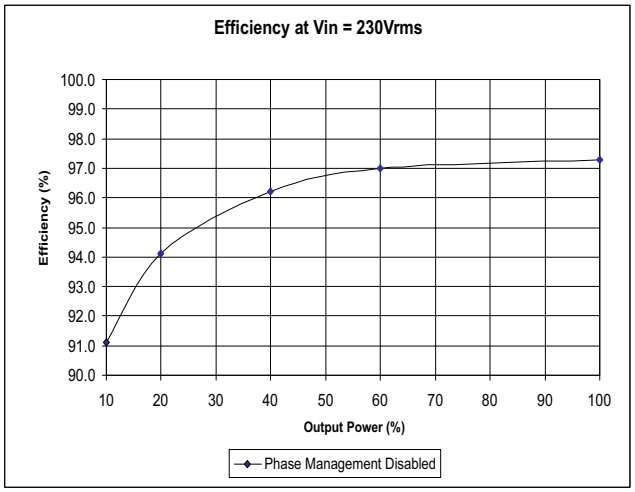

Figure 6. Efficiency at 230 V_{RMS}, Without Phase Management

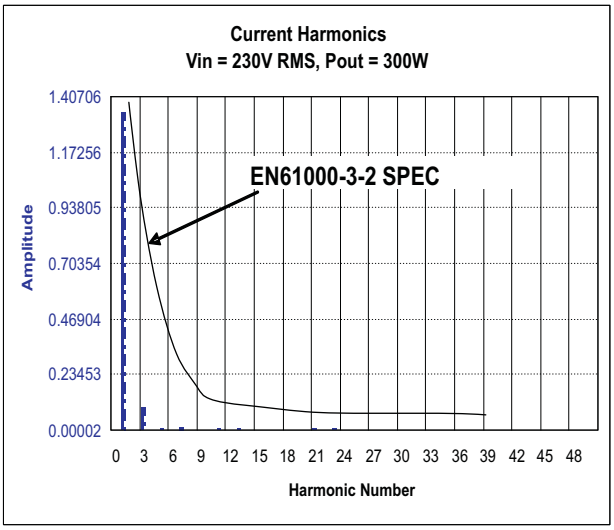

Figure 7. Current Harmonics

6.1 Output Ripple Voltage at Full Load

Figure 8 illustrates the output ripple voltage.

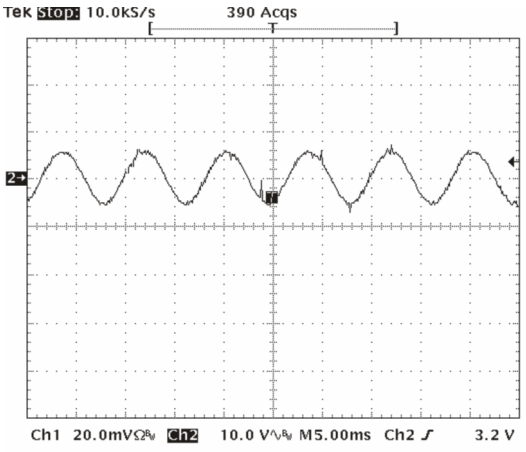

Figure 8. V_{OUT} Ripple, P_{OUT} = 300 W

6.2 Input Ripple Current Cancellation

Figure 9 through Figure 14 show the input current ($M_1 = I_{L1} + I_{L2}$), Inductor Ripple Current (I_{L1}, I_{L2}) versus rectified line voltage. From these graphs, it can be observed that interleaving reduces the magnitude of input ripple current caused by the inductor ripple current.

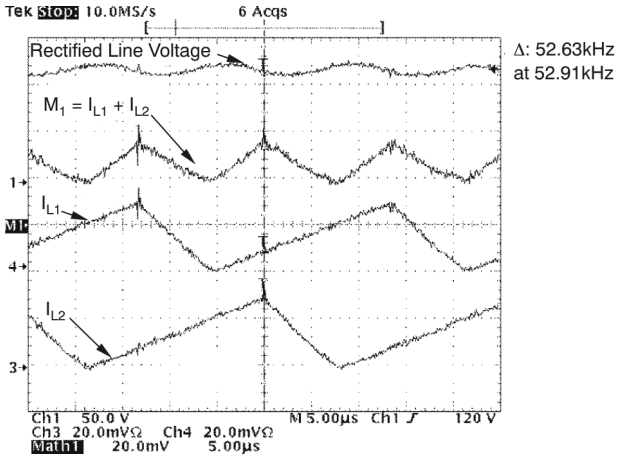

Figure 9. Inductor and Input Ripple Current at 85 V_{RMS} at Peak of Line Voltage

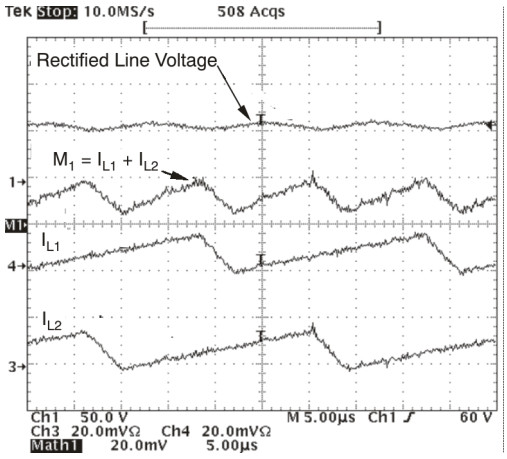

Figure 10. Inductor and Input Ripple Current at 85 V_{RMS} Input at Half the Line Voltage

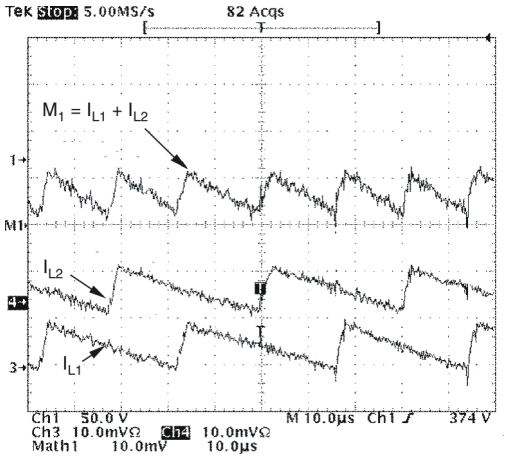

Figure 11. Inductor and Input Ripple Current at 265 V_{RMS} Input at Peak Line Voltage

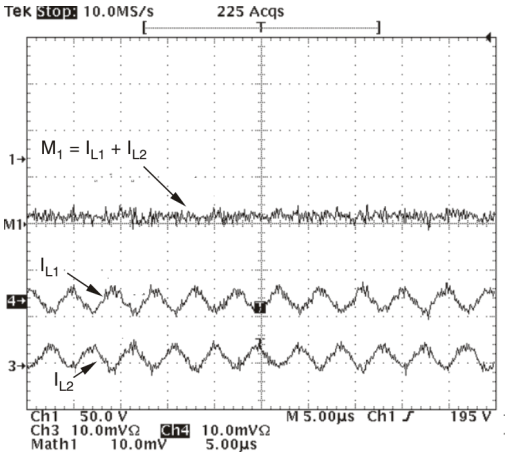

Figure 12. Inductor and Input Ripple Current at 265 V_{RMS} Input at Half Peak Line Voltage

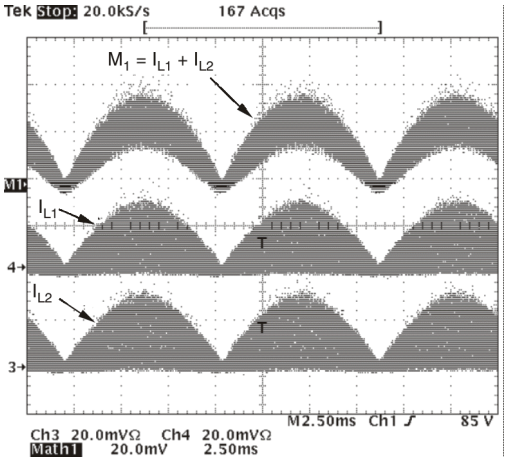

Figure 13. Inductor and Input Ripple Current at V_{IN} = 85 V_{RMS}, P_{OUT} = 300 W

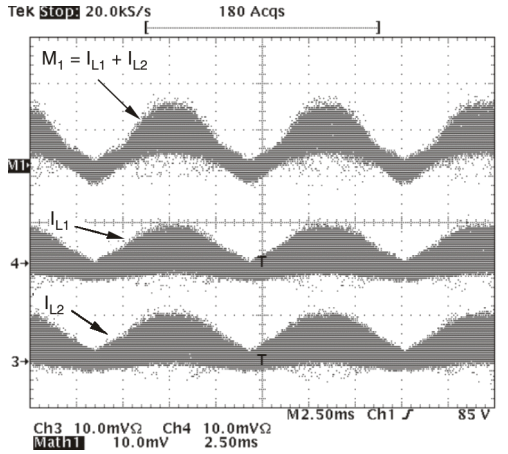

Figure 14. Inductor and Input Ripple Current at V_{IN} = 265 V_{RMS}, P_{OUT} = 300 W

6.3 Startup Characteristics

Figure 15 and Figure 16 illustrate the UCC28063EVM-723 startup characteristics.

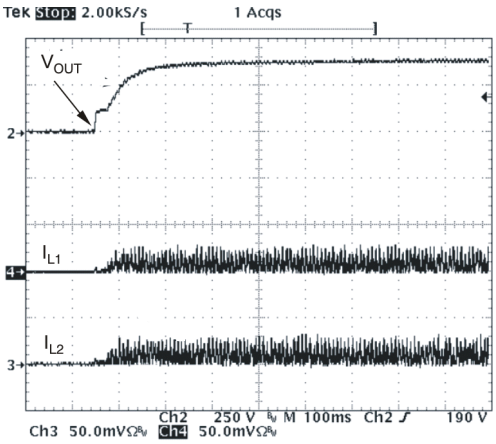

Figure 15. Start-Up at V_{IN} = 85 V_{RMS}, P_{OUT} = 300 W

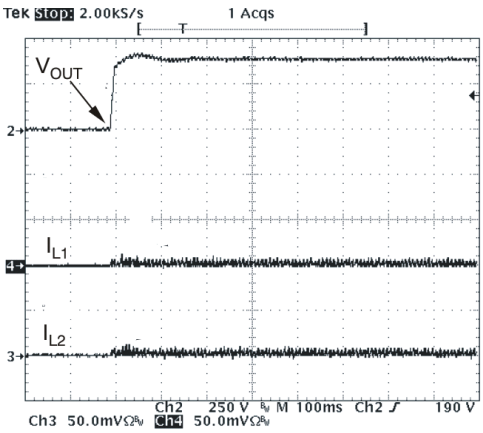

Figure 16. Start-Up at V_{IN} = 265 V_{RMS}, P_{OUT} = 0 W

6.4 Brownout Protection

The UCC28063 has a brownout protection that shuts down both gate drives (GDA and GDB) when the VINAC pin detects that the RMS input voltage is too low. This EVM was designed to go into a brownout state when the line drops below 64 V_{RMS}. Once the UCC28063 control device has determined that the input is in a brownout condition, a 400-ms timer starts to allow the line to recover before shutting down the gate drivers. After 400 ms of brownout, both gate drivers turn off, as shown in Figure 17 and Figure 18.

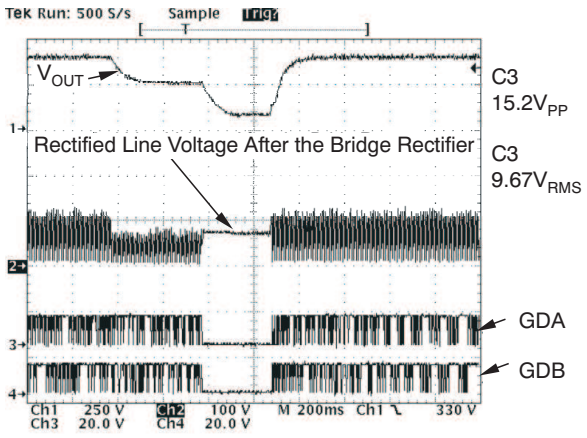

Figure 17. Brownout at 85 V_{RMS}

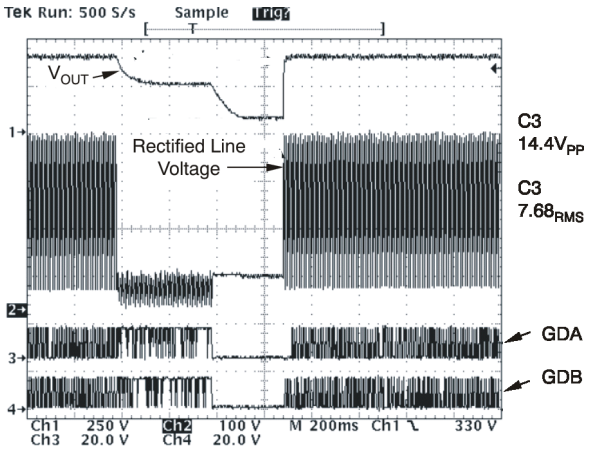

Figure 18. Brownout at 265 V_{RMS}

6.5 Line Transient

A line transient test was conducted with an ac source on the reference design. The line was varied from 230 V_{RMS} to 115 V_{RMS} to 230 V_{RMS} and the transient response was evaluated in each case. From the oscilloscope image in Figure 19, it can be observed that the output recovered from line transients within 300ms at full load.

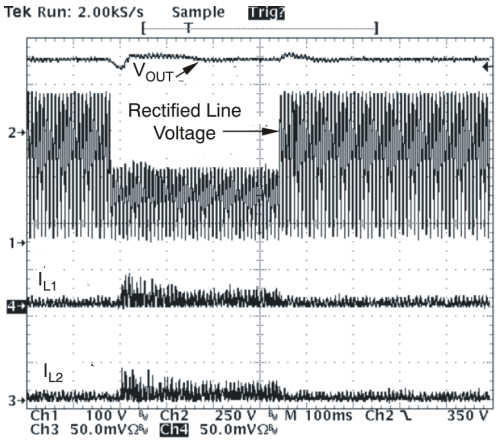

Figure 19. Line Transient, P_{OUT} = 300W

7 Reference Design Assembly Drawing

Figure 20 and Figure 22 show the top and bottom layers (respectively) of the UCC28063EVM-723.

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 UCC28063EVM-723 PCBs.

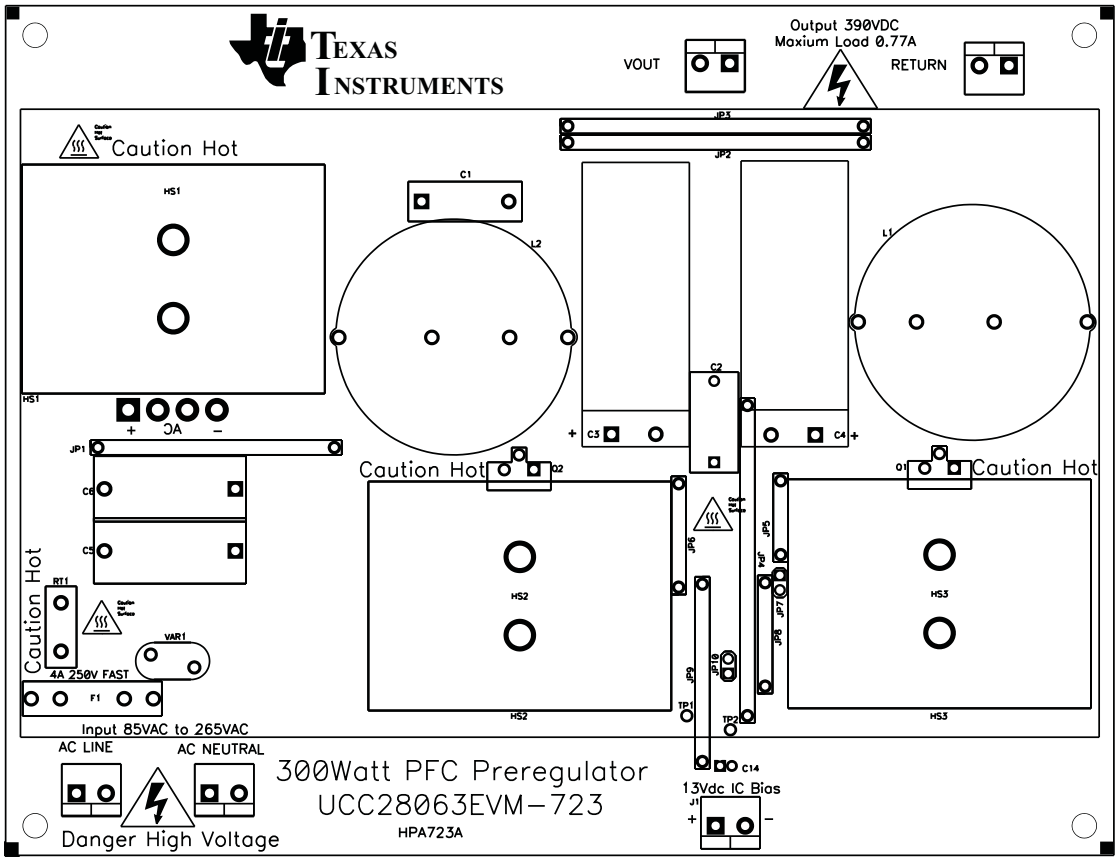

Figure 20. Top Layer Assembly

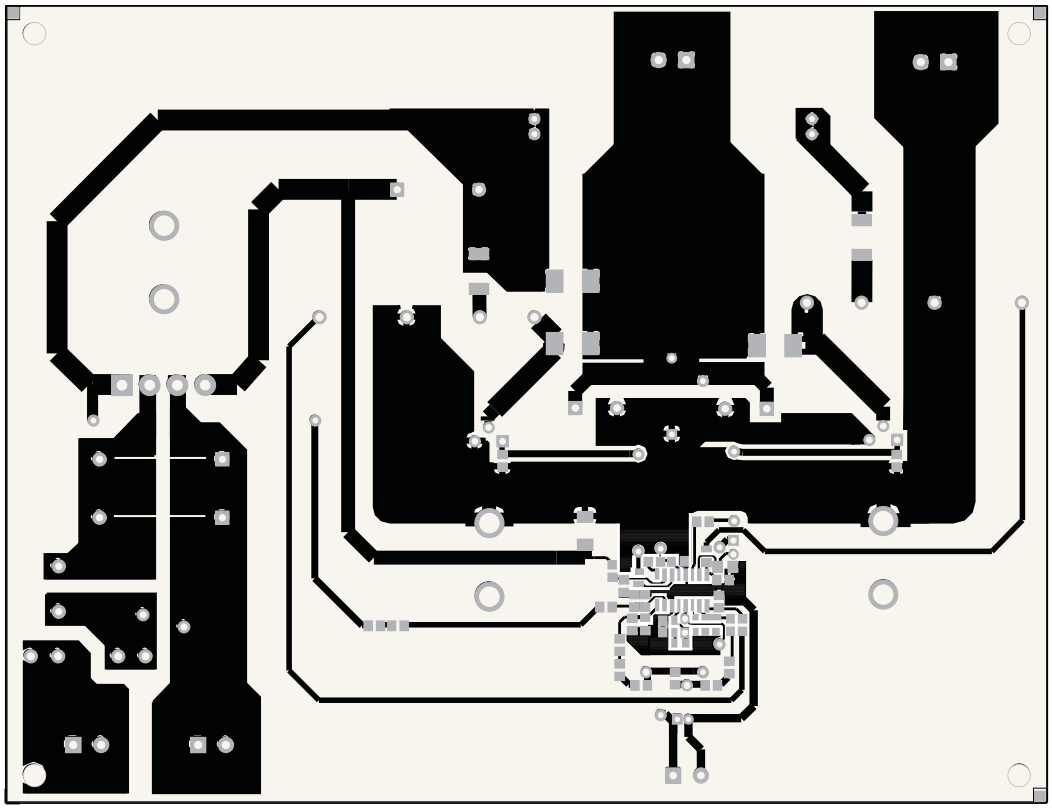

Figure 21. Bottom Layer Copper

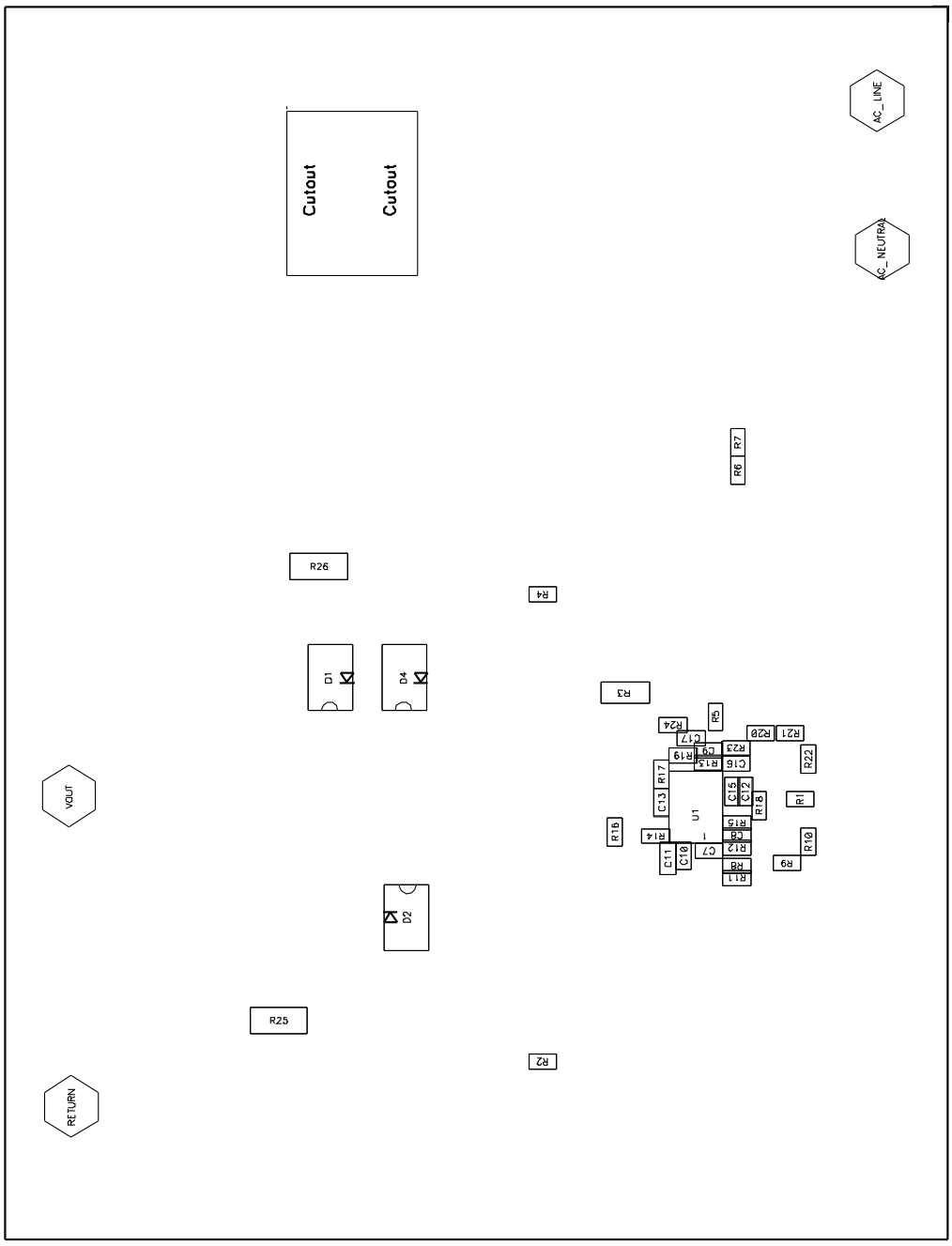

Figure 22. Bottom Layer Assembly

8 List of Materials

Table 2 lists the EVM components as configured according to the schematics (see Section 4).

Table 2. List of Materials

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
4	AC_LINE, AC_NEUTRAL, RETURN, VOUT	Terminal block, 2 pin, 15 A, 5.1 mm	ED120/2DS	OST
1	C1	Capacitor, film, 275VAC, 20±%, 0.1 µF, 0.689 x 0.236 inch	ECQU2A104BC1	Panasonic
1	C11	Capacitor, ceramic, 16 V, X7R, 10%, 220 nF, 1206	Std	Std
2	C12, C13	Capacitor, ceramic, 16 V, X7R, 10%, 2.2 µF, 0805	Std	Std
1	C14	Capacitor, aluminum, 35 V, ±20%, 22 µF, 0.200 * 0.435 inch	ECA-1VM220	Panasonic
1	C15	Capacitor, ceramic, 25 V, X7R, 10%, 820 pF, 0805	Std	Std
1	C17	Capacitor, ceramic, 25 V, X7R, 10%, 10 nF, 0805	Std	Std
1	C2	Capacitor, polyester, 630 V, 10%, 0.047 µF, 0.256 x 0.650 inch	ECQ-E6473KZ	Panasonic
2	C3, C4	Capacitor, aluminum, 450 VDC, ±20% , 100 µF, 18 x 40 mm	EKXG451ELL101 MM40S	Nippon Chemi-con
2	C5, C6	Capacitor, film, 275 VAC, 20±%, 0.47 µF, 0.236 X 0.591	ECQ-U2A474MG	Panasonic
2	C7, C10	Capacitor, ceramic, 25 V, X7R, 10%, 22 pF, 0805	Std	Std
3	C8, C9, C16	Capacitor, ceramic, 25 V, X7R, 10%, 1.2 nF, 0805	Std	Std
3	D1, D2, D4	Diode, 3000 mA, 600 V, SMC	MURS360T3	On Semi
1	D3	Diode, bridge, 6 A, 600 V, BU6	GBU6J	Vishay
2	F1	Fuse clip, 5x20 mm	0100056H	Wickmann
3	HS1, HS2, HS3	Heatsink, universal-mount TO-220, 7-345-2PP, 1.500 x 2.000 inch	7-345-2PP	IERC-CTS
1	J1	Terminal block, 2 pin, 15 A, 5.1 mm, ED1609-ND, 0.40 x 0.35 inch	ED1609	OST
3	JP1, JP2, JP3	Jumper, 2.000 inch length, PVC insulation, AWG 22, 0.035 inch dia.	923345-20-C	3M
1	JP4	Jumper, 2.100 inch length, PVC insulation, AWG 22, 0.035 inch dia.	923345-21-C	3M
1	JP5	Jumper, 0.500 inch length, PVC insulation, AWG 22, 0.035 inch dia	923345-05-C	3M
2	JP6, JP8	Jumper, 0.700 inch length, PVC insulation, AWG 22	923345-07-C	3M
1	JP7	Jumper, 0.100 inch length, non-insulated, AWG 22	923345-01-C	3M
1	JP10	Header, 2-pin, 100-mil spacing, 0.100 inch x 2	PEC02SAAN	Sullins
1	JP9	Jumper, 1.2 inch length, PVC insulation, AWG 22, 0.035 inch dia.	923345-20-C	3M
2	L1, L2**	Inductor, boost PFC with aux. 330 uH @ 5.3 A PK, 1.555 Dia. inch	CTX16-17769R	Cooper
2	Q1, Q2	MOSFET, N-channel, 500 V, 11 A, 520 mΩ, TO-220V	IRFB11N50APbF	IR

Table 2. List of Materials (continued)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	R1	Resistor, chip, 1/10 W, 1%, 51.1 Ω, 0805	Std	Std
2	R11, R14	Resistor, chip, 1/10 W, 1%, 20.5 kΩ, 0805	Std	Std
2	R12, R13	Resistor, chip, 1/10 W, 1%, 133 kΩ, 0805	Std	Std
1	R15	Resistor, chip, 1/10 W, 1%, 121 kΩ, 0805	Std	Std
2	R16, R19	Resistor, chip, 1/10 W, 1%, 5.11 Ω, 0805	Std	Std
1	R18	Resistor, chip, 1/10 W, 1%, 9.53 kΩ, 0805	Std	Std
3	R2, R4, R17	Resistor, chip, 1/10 W, 1%, 10.0 kΩ, 0805	Std	Std
1	R23	Resistor, chip, 1/10 W, 1%, 82.5 kΩ, 0805	Std	Std
1	R24	Resistor, chip, 1/10 W, 1%, 100 Ω, 0805	Std	Std
2	R25, R26	Resistor, chip, 1 W, 5%, 0 Ω, 2512	Std	Std
1	R3	Resistor, chip, 1/2 W, 1%, 0.015 Ω, 2010	WSL2010R0150FEA	Vishay
3	R5, R6, R7	Resistor, Chip, 1/10 W, 1%, 2.87 MΩ	Std	Std
5	R8, R9, R20, R21, R22	Resistor, chip, 1/10 W, 1%, 2.74 MΩ, 0805	Std	Std
1	R10	Resistor, Chip, 1/10 W, 1%, 3.01 MΩ, 0805	Std	Std
1	RT1	Thermistor, NTC, 5 Ω, 6 A, 5 Ω, 0.180 X 0.550 inch	CL-40	Thermometrics
2	TP1, TP2	Pin, thru hole, tin plate, for 0.062 PCB's, K24A/M, 0.039 inch	K24A/M	Vector
1	U1	Interleave PFC Controller, SO16	UCC28063D	TI
1	VAR1	Varistor 275 V RMS, 0.472 x 0.213 inch	S10K275E2	Epcos
1	PCB	HPA343 printed circuit board	HPA343	
1	X1 @ F1	4 A, fast acting fuse, BK/GDA-4A, 5mmX20mm	BK/S501-4-R	Cooper/Bussman
6	"X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Nut #4-40 (steel)	Std	Std
6	"X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Pan head screw #4-40X3/8 (steel)	Std	Std
1	X1 D3 and HS1	Thermal grease	Std	Std
6	"X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Split lock washer #4(steel)	Std	Std
6	"X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2"	Nylon shoulder washer #4	3049	Keystone Electronics
2	"X1 @ HS2 and Q1, HS3 and Q2"	Thermal pad silicon TO220	3223-07FR-51	BERQUIST
4	1903C	Standoff hex .500/6-32THR nylon	1903C	Keystone Electronics
4	4824	Nut	4824	Keystone Electronics

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of xxx V to xxx V and the output voltage range of xxx V to xxx V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than xxx° C. The EVM is designed to operate properly with certain components above xxx° C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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http://www.tij.co.jp

EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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