

EVM User's Guide: UCC28750EVM-071 UCC287502

Using the UCC28750EVM-071 60-W AC to DC Converter



Description

The UCC28750EVM-071 is a 60-W evaluation module (EVM) for evaluating an off-line power AC to DC flyback converter. The UCC28750EVM-071 is intended for evaluation purposes and is not intended to be an end product. The UCC28750EVM-071 converts 85- V_{RMS} to 265- V_{RMS} input voltage down to 24- V_{DC} , capable of delivering 60 W of output power. This evaluation module uses the UCC287502 Constant-Voltage Flyback Controller Using Opto-Coupled Feed-Back in a 60 W converter to provide 2.5 A of constant charge current. The input accepts a voltage range of 85 VAC to 265 VAC. Depending upon the operating conditions, the control law algorithm modulates the switching frequency or the peak primary current to satisfy the power transfer requirements. The programmable slope compensation enables both CCM and DCM operation. Power-boost mode provides additional power for momentary peak demand.

Get Started

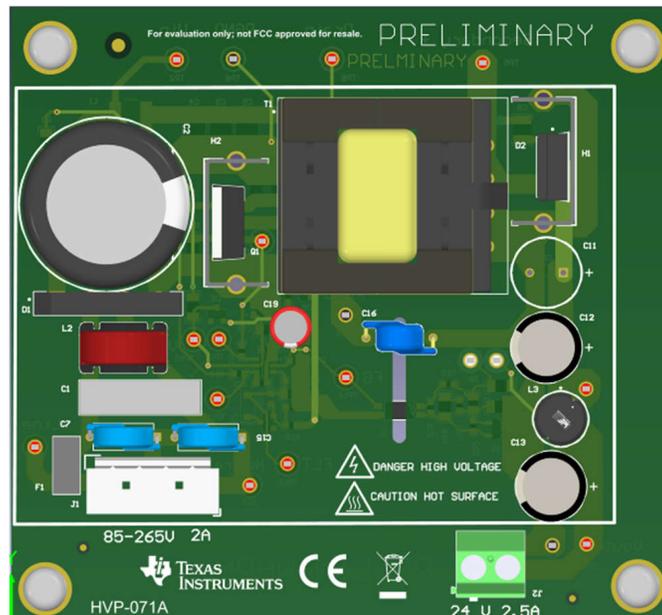
1. Read and study this user's guide completely before evaluating
2. Order the [UCC28750EVM-071](#) for evaluation if step 1 and 2 is met
3. Setup and test the UCC28750EVM-071 per user's guide instructions

Features

- Regulated 24 V, +/-5%, 60 W Output
- Wide Input Range 85 to 265-V RMS
- Max Load Efficiency > 90%

Applications

- Isolated offline AC/DC power supply
- [Industrial AC/DC](#) for grid infrastructure, appliances
- Audio, printer, TV, set-top box offline AC/DC
- [Battery charger](#)
- [Merchant DIN rail power supply](#), [Server PSU](#)
- [Electricity meter](#)
- [String inverter](#), [Micro inverter](#)
- [Small home appliances](#), [Major appliances](#), AC indoor/outdoor unit



UCC28750EVM-071

1 Evaluation Module Overview

1.1 Introduction

The UCC28750EVM-071 has frequency foldback and burst mode enable higher efficiency and standby performance at light load. Opto-coupled feed-back maintains a tightly regulated output with fast dynamic response to load transients. The controller further enhances the efficient operation with valley switching. The UCC287502 also includes a omprehensive protection features including UVLO/OVLO, OTP, OPP, OVP, OCP, brown-out detection, and options to latch and auto-restart. The UCC287502 also uses dithering of the gate drive helps to ease EMI compliance. This user's guide provides the schematic, component list, assembly drawing, art work, and test set up necessary to evaluate the UCC287502 in a typical off-line converter application.

1.2 Kit Contents

- An Evaluation Module (EVM) TI part number UCC28750EVM-071
- EVM Disclaimer and Read Me material

1.3 Specifications

Table 1-1. UCC28750EVM-071 Electrical Performance Specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS						
V_{IN}	Input voltage (RMS)		85	115/230	265	V
f_{LINE}	Line frequency		47	50/60	63	Hz
P_{STBY}	No load input power	$V_{IN} = 115\text{ V} / 230\text{ V RMS}, I_{OUT} = 0\text{ A}$			750	mW
OUTPUT CHARACTERISTICS						
V_{OUT}	Output voltage	$V_{IN} = 85 - 265\text{ V AC}, I_{OUT} = 0\text{ A}-2.5\text{ A}$	22.8	24	25.2	V
V_{OUT}	Output ripple voltage	$V_{IN} = \text{nom}, I_{OUT} = 0-2.5\text{ A},$			500	mVpp
I_{OUT}	Output current	$V_{IN} = \text{min to max}$	0.0		2.5	A
SYSTEMS CHARACTERISTICS						
Average efficiency	25%, 50%, 75%, 100% load average at nominal input voltages	115-V / 230-V RMS input		89%		
	Operating temperature range	$V_{IN} = \text{min to max}, I_{OUT} = \text{min to max}$		25		°C

2 Hardware

2.1 Test Points

Table 2-1. Test Point Functions

TEST POINTS	DESCRIPTION
TP1	AC LINE
TP2	AC Neutral
TP3	Capacitor Voltage C9..C12
TP4	Output Supply
TP5	Secondary Switch Node
TP6	Output Return
TP7	AC Neutral
TP8	Primary Switch Node
TP9	Output Return
TP10	UCC287502 Supply Voltage
TP11	Feedback Test Point
TP12	UCC287502 DRV Pin
TP13	Q1 Gate
TP14	Feedback Test Point
TP15	UCC287502 CS Pin
TP16	UCC287502 FB Pin
TP17	UCC287502 OPP Pin
TP18	Primary Ground

2.2 Test Setup

2.2.1 Test Setup Requirements

Safety: This evaluation module is not encapsulated and there are voltages that are much greater than 50 V_{DC}.

WARNING

If you are not trained in the proper safety of handling and testing power electronics please do not test this evaluation module.

Voltage Source: Isolated AC source or variable AC transformer capable of 265 V_{AC} cable of handling 80 W

Voltmeter: Digital voltage meter

Power Analyzer: Capable of measuring 1 mW to 10 W of input power and capable of handling 265-V RMS input voltage. Please read the power analyzer's user manual for proper setup.

Oscilloscope:

- 4 Channel 100 MHz.
- Probes capable of handling 600 V.

Output Load: Resistive or electronic load capable handling 60 W at 24 V.

Recommended Wire Gauge: Insulated 22 AWG.

2.2.2 Test Setup Diagram

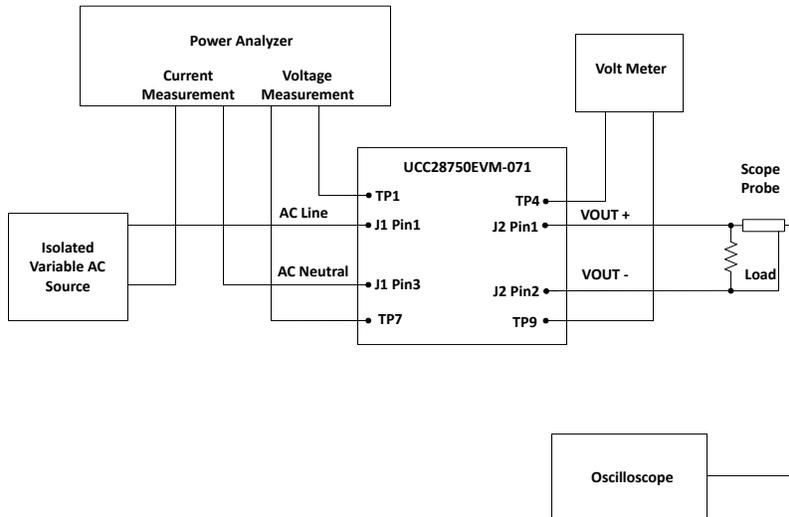


Figure 2-1. UCC28750EVM-001 Test Setup Diagram

2.3 Best Practices

CAUTION



CAUTION



This EVM has voltages greater than 50 V DC and 50 V AC when power is applied to the input. Caution must be taken when evaluating the EVM.

CAUTION



This EVM has components that reach temperatures of greater than 55°C. Caution must be taken when evaluating the EVM.

2.3.1 General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines



Always follow TI's setup and application instructions, including use of all interface components within the recommended electrical rated voltage and power limits. Always use electrical safety precautions to help verify your personal safety and those working around you. Contact TI's Product Information Center <http://support/ti.com> for further information.

Save all warnings and instructions for future reference.

WARNING

Failure to follow warnings and instructions can result in personal injury, property damage or death due to electrical shock and burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is *intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments.* If you are not suitably qualified, then immediately stop from further use of the HV EVM.

1. Work Area Safety

- a. Keep work area clean and orderly.
- b. Qualified observers must be present anytime circuits are energized.
- c. Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
- d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
- e. Use stable and nonconductive work surface.
- f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.

2. Electrical Safety

As a precautionary measure, it is always a good engineering practice to assume that the entire EVM can have fully accessible and active high voltages.

- a. De-energize the TI HV EVM and all the inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
- b. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment connection, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
- c. After EVM readiness is complete, energize the EVM as intended.

WARNING

While the EVM is energized, never touch the EVM or the electrical circuits, as they can be at high voltages capable of causing electrical shock hazard.

3. Personal Safety

- a. Wear personal protective equipment (for example, latex gloves or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks to protect from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

3 Implementation Results

3.1 Performance Data and Typical Characteristic Curves

3.1.1 Efficiency

Table 3-1. Efficiency Test Data

$V_{IN\ RMS}$	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	EFFICIENCY
85	24.2	0.00	0.059	0	NA
85	24.145	0.055	1.573	1.3273	84.38
85	24.143	0.197	5.353	4.763	88.98
85	24.137	0.46	12.278	11.104	90.43
85	24.132	0.696	18.566	16.813	90.55
85	24.13	0.968	25.8	23.357	90.53
85	24.127	1.2119	32.462	29.239	90.07
85	24.125	1.451	39	35	89.74
85	24.122	1.6398	44.17	39.554	89.54
85	24.12	1.887	50.88	45.53	89.48
85	24.113	2.231	60.4	53.83	89.12
85	24.1	2.726	73.9	65	88.97
115	24.21	0.000	0.065	0.000	NA
115	24.145	0.055	1.57	1.328	84.58
115	24.136	0.196	5.35	4.747	88.73
115	24.131	0.46	12.26	11.09	90.45
115	24.126	0.698	18.56	16.85	90.78
115	24.122	0.972	25.76	23.45	91.03
115	24.120	1.211	32.09	29.21	91.02
115	24.115	1.449	38.41	34.96	91.02
115	24.113	1.74]	46.25	42.02	90.85
115	24.112	1.88	49.97	45.35	90.75
115	24.110	2.228	59.2	53.73	90.76
115	24.108	2.72	72.6	65	89.53
230	24.227	0.000	0.102	0.000	NA
230	24.147	0.055	1.6628	1.328	80
230	24.138	0.197	5.512	4.759	86.34
230	24.135	0.46	12.425	11.106	89.38
230	24.135	0.696	18.644	16.812	90.17
230	24.133	0.969	25.7	23.379	90.96
230	24.132	1.2113	32.1	29.219	91.02
230	24.128	1.4512	38.5	35.017	90.95
230	24.123	1.6398	43.418	39.548	91.08
230	24.121	1.8872	49.95	45.51	91.11
230	24.118	2.23	59	53.83	91.23
230	24.115	2.7287	72.33	65.813	90.99
265	24.32	0	0.151	0	NA

Table 3-1. Efficiency Test Data (continued)

V _{IN} RMS	V _{OUT}	I _{OUT}	P _{IN}	P _{OUT}	EFFICIENCY
265	24.144	0.055	1.7	1.33	78.2
265	24.134	0.197	5.5925	4.7635	85.17
265	24.132	0.46	12.56	11.108	88.43
265	24.13	0.697	18.76	16.83	89.7
265	24.128	0.968	25.903	23.348	90.13
265	24.126	1.211	32.224	29.21	90.64
265	24.125	1.4513	38.53	35.018	90.88
265	24.122	1.64	43.54	39.55	90.83
265	24.12	1.8872	50.06	45.52	90.91
265	24.118	2.231	59.13	53.813	91
265	24.115	2.72	72.09	65.63	91.03

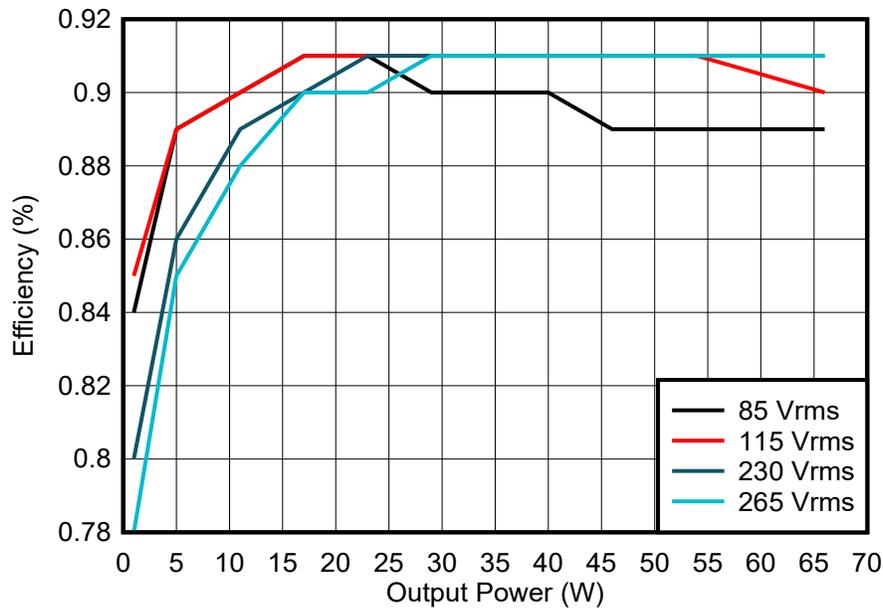


Figure 3-1. Efficiency

Note

The inductor L1, which is mounted on the PCB and shown in BOM needs to be removed and shorted out to get best efficiency results.

Standby Power	
AC Input Voltage (Volts)	Power (mW)
85	59
115	65
230	102
265	151

3.1.2 Startup

CH1 = V_{BULK} , CH2 = V_{CC} , CH3 = V_{GATE} , CH4 = V_{OUT}



Figure 3-2. Start-up Waveforms at 85Vac and No Load



Figure 3-3. Start-up Waveforms at 85Vac and Full Load



Figure 3-4. Start-up Waveforms at 115Vac and No Load

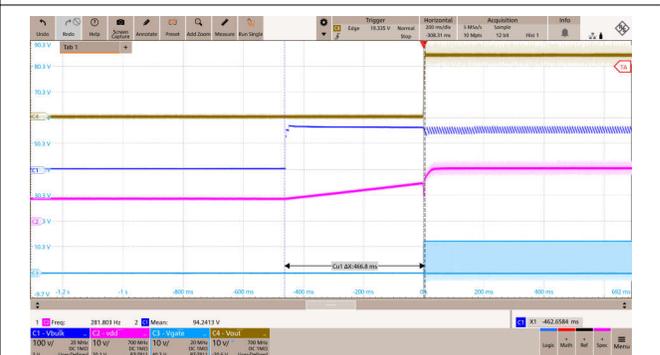


Figure 3-5. Start-up Waveforms at 115Vac and Full Load

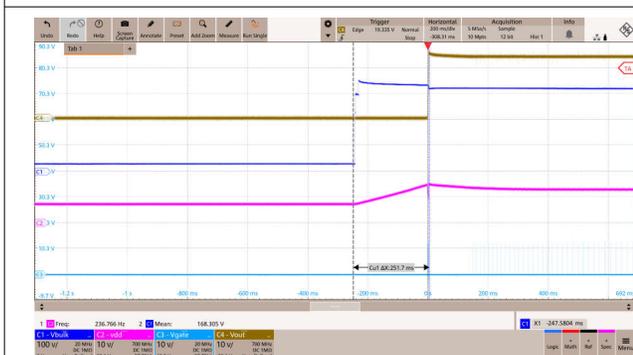


Figure 3-6. Start-up Waveforms at 230Vac and No Load

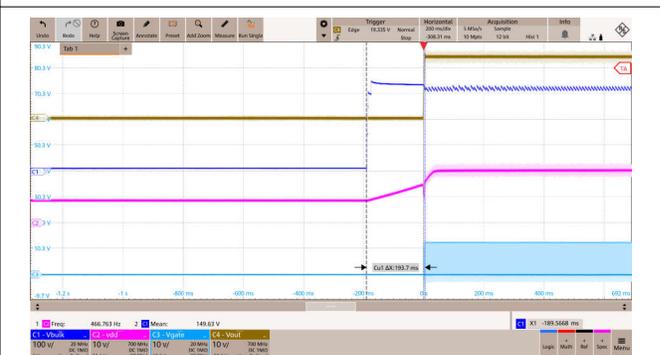


Figure 3-7. Start-up Waveforms at 230Vac and Full Load



Figure 3-8. Start-up Waveforms at 265Vac and No Load



Figure 3-9. Start-up Waveforms at 265Vac and Full Load

3.1.3 Load Transients

CH1 = V_{OUT} , CH4 = I_{OUT}

Load = 0.100A to 2 .5A, 1 kHz, 50% Duty Cycle

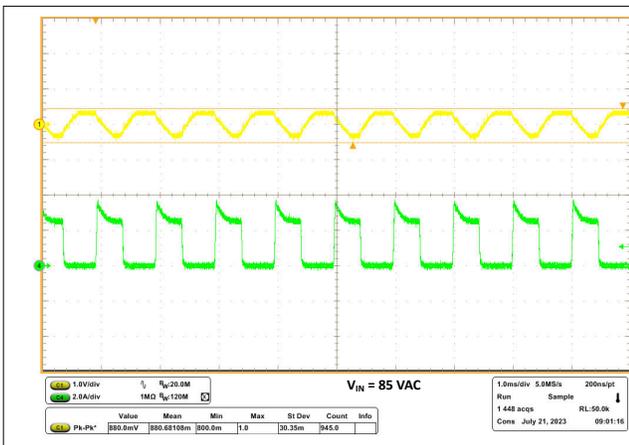


Figure 3-10. Load Transients at 85Vac

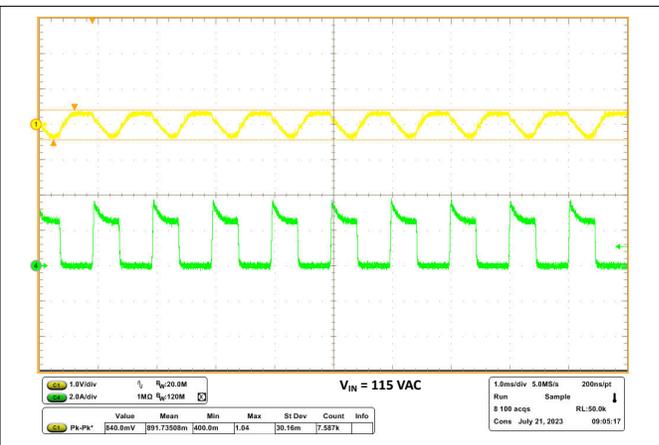


Figure 3-11. Load Transients at 115Vac

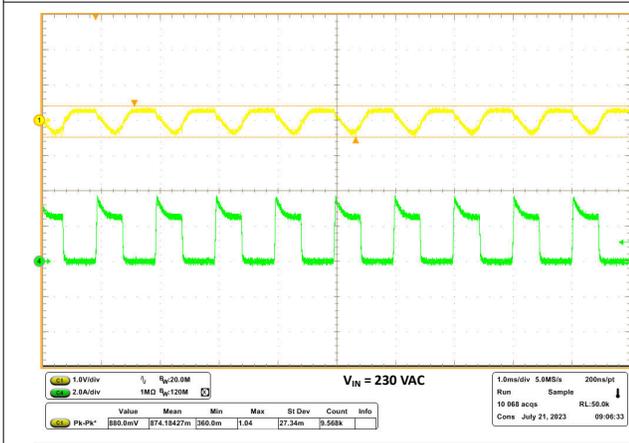


Figure 3-12. Load Transients at 230Vac

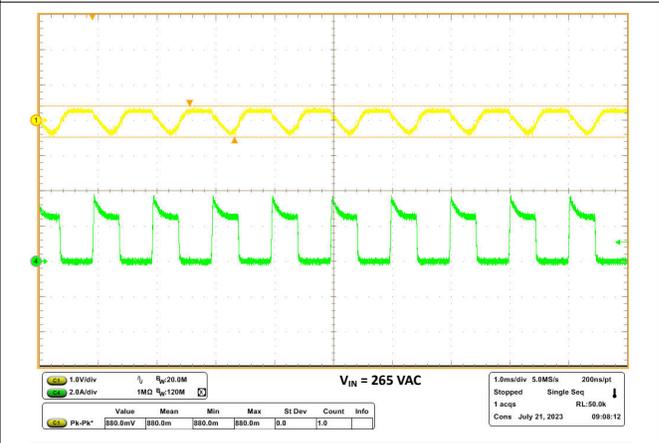
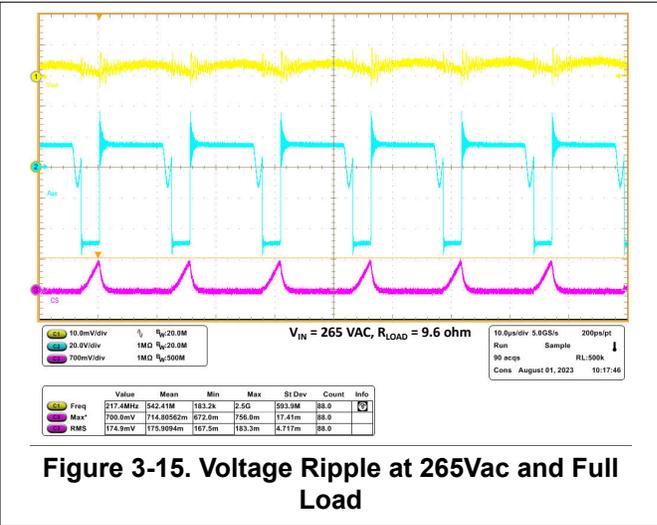
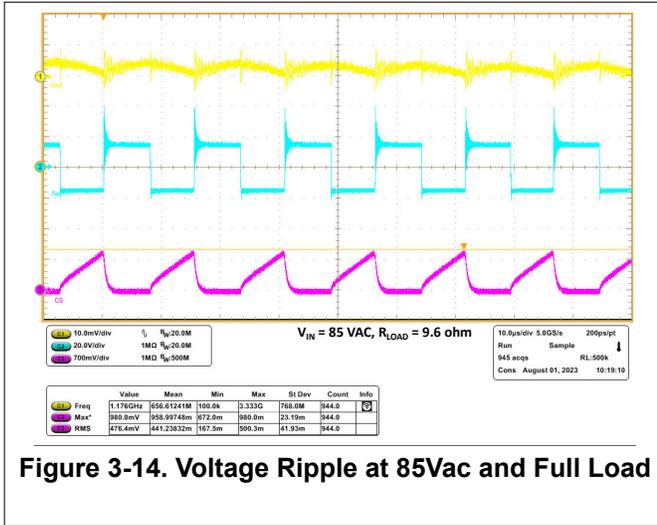


Figure 3-13. Load Transients at 265Vac

3.1.4 Output Ripple Voltage at Full Load

CH1 = V_{OUT} , CH2 = V_{AUX} , CH3 = V_{CS}



3.1.5 Q1 Drain Voltage Evaluation

CH1=V_{Q1d}, CH3 = V_{GATE}, CH4 = V_{OUT}

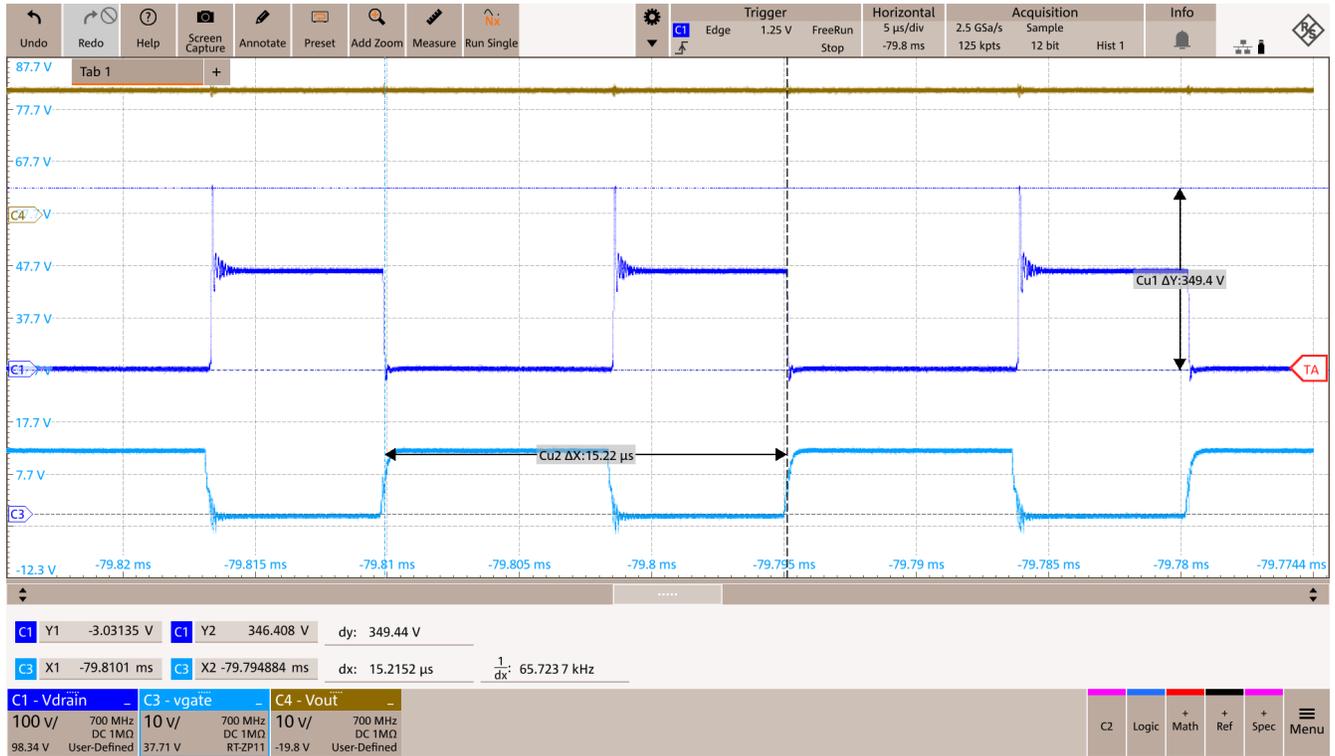


Figure 3-16. Steady State Waveform at 85Vac



Figure 3-17. Steady State Waveform at 85Vac

4 Hardware Design Files

4.1 Schematic

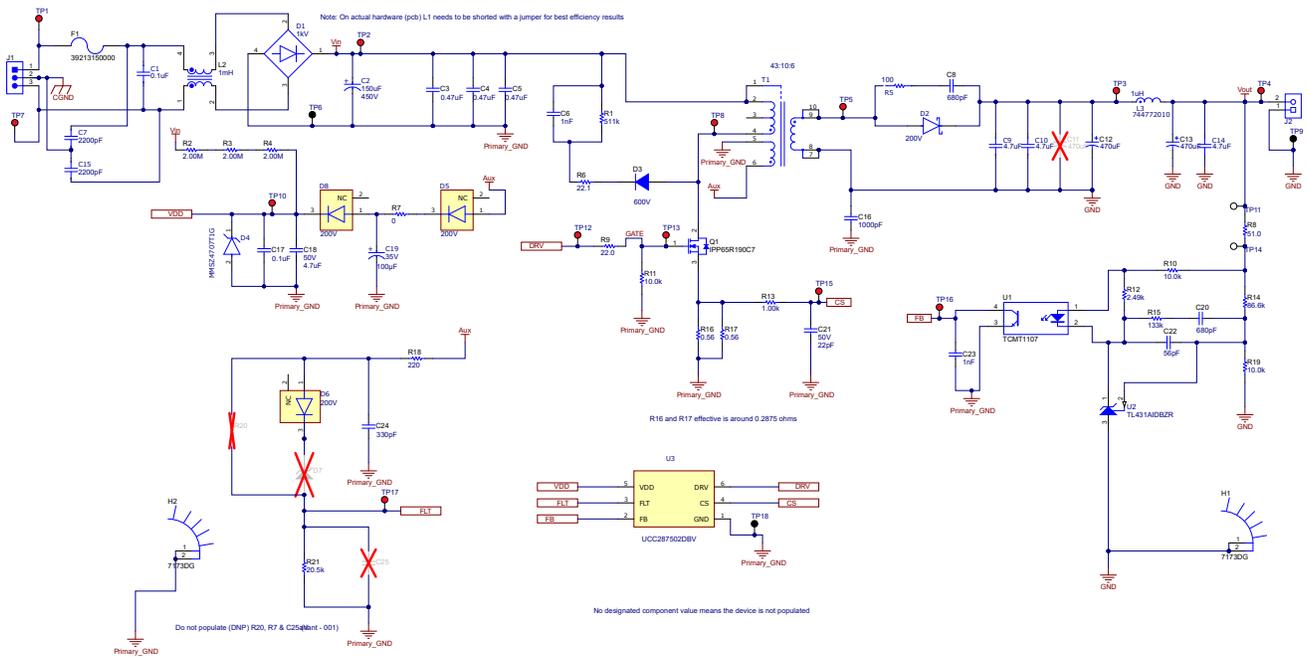


Figure 4-1. UCC28750EVM-071 Schematic

4.2 EVM Assembly and Layout

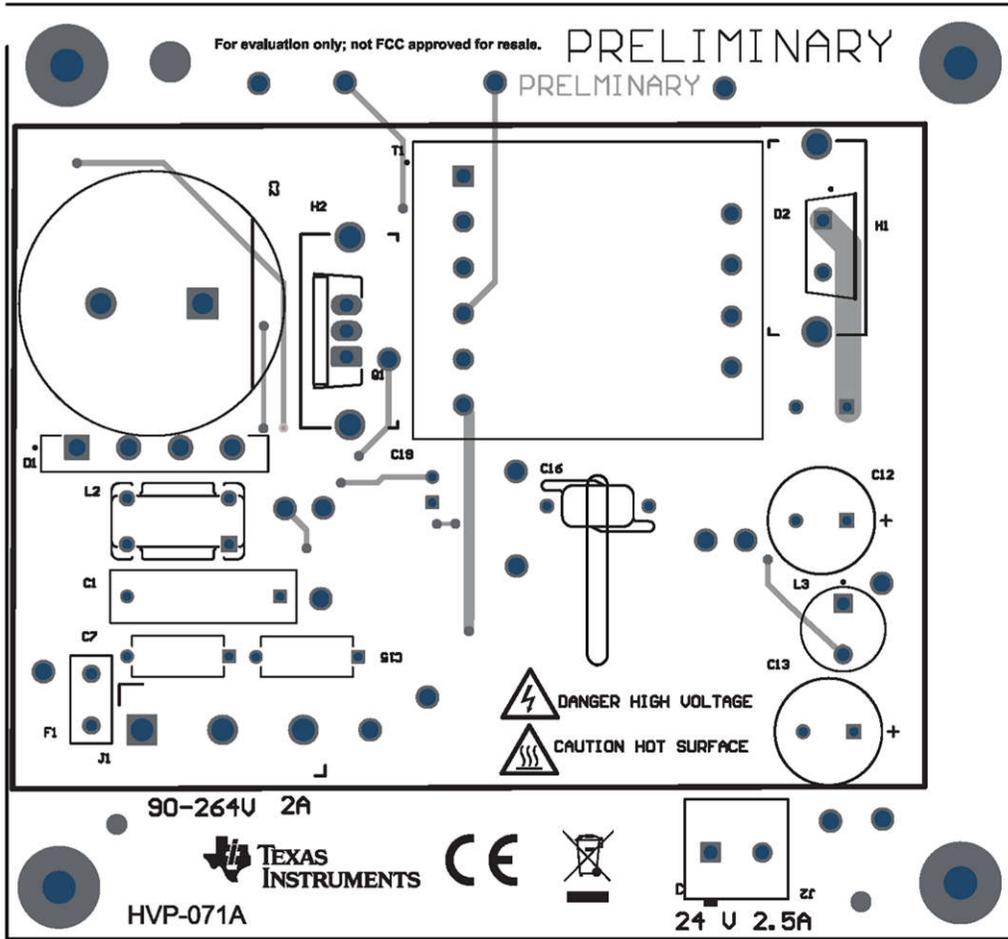


Figure 4-2. EVM Assembly (Top View)

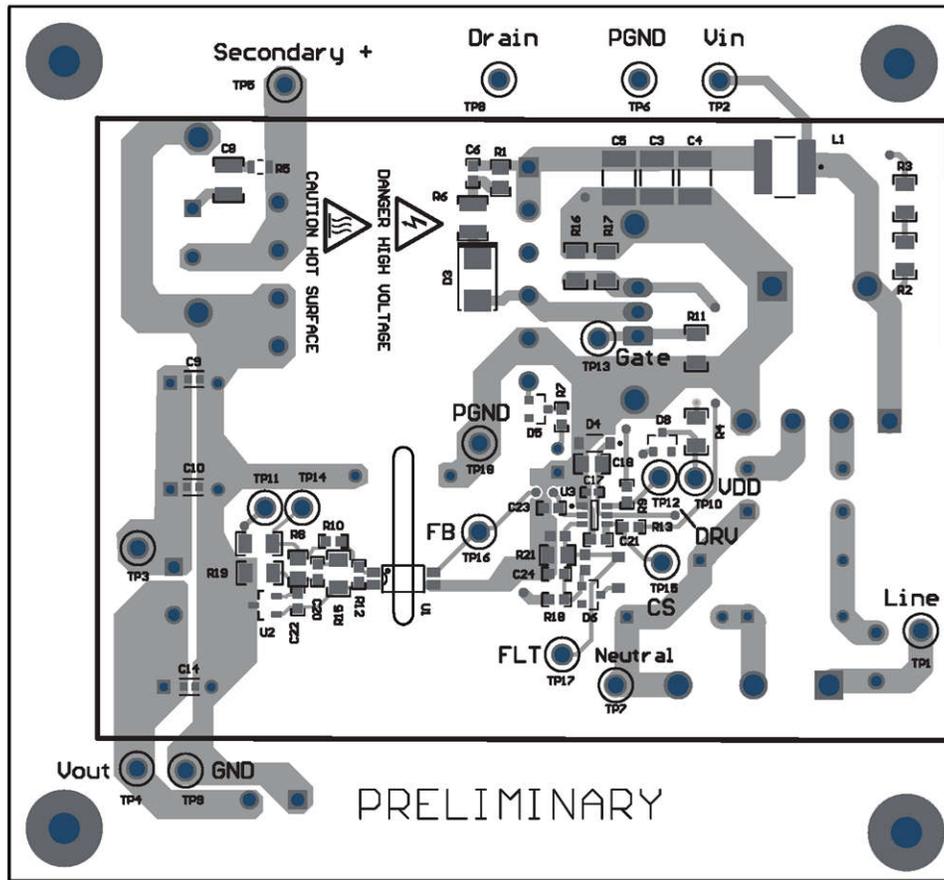


Figure 4-3. EVM Assembly/Layout (Bottom View)

4.3 Bill of Materials

UCC28750EVM-071 bill of materials as shown in [Table 4-1](#).

Table 4-1. UCC28750EVM-001 Bill of Materials

QTY	DES	DESCRIPTION	PART NUMBER	MANUFACTURER
1	C1	Cap Film Suppression X2 0.1uF 560VDC/275VAC PP 10% (18 X 5 X 11mm) Radial Plastic Rectangular Can 15 mm 110C Bulk	R46KI3100JBM1K	Kemet
1	C2	150 µF 450 V Aluminum Electrolytic Capacitors Radial, Can - Snap-In 5000 Hrs @ 105°C	450VXH150MEFCSN25X30	Rubycon
3	C3, C4, C5	CAP, CERM, 0.47 uF, 500 V, +/- 10%, X7R, 1812	1812Y5000474KXTWS2	Knowles Capacitors
1	C6	CAP, CERM, 1000 pF, 250 V, +/- 10%, X7R, 0603	GRM188R72E102KW07D	MuRata
2	C7, C15	Cap Ceramic Disc 2200 pF 20% 250VAC Thru-Hole 9.0x4.0x10.0 Ammo pack	DE1E3RA222MN4AN01F	Murata
1	C8	680 pF ±5% 200 V Ceramic Capacitor C0G, NP0 1210 (3225 Metric)	12102A681JAT2A	KYOCERA AVX
3	C9, C10, C14	Cap Ceramic 4.7uF 35 V X5R ±10% Pad SMD 0603 +85°C T/R	CL10A475KL8NRNC	Samsung
3	C12, C13	CAP, AL, 470 uF, 35 V, +/- 20%, TH	EKZE350ELL471MJ20S	Chemi-Con
1	C16	CAP, CERM, 1000 pF, V, +/- 20%, Y5V, D7xT5mm	C901U102MYVDBA7317	Kemet
1	C17	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0402	C1005X7R1H104K050BE	TDK
1	C18	CAP, CERM, 4.7 uF, 50 V, +/- 10%, X7S, 0805	GRM21BC71H475KE11K	MuRata
1	C19	100 µF 35 V Aluminum Electrolytic Capacitors Radial, Can 5000 Hrs @ 105°C	860040573004	Würth Electronics
1	C20	CAP, CERM, 680 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H681JA01D	MuRata
1	C21	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0603	GRM1885C1H220JA01D	MuRata
1	C22	CAP, CERM, 56 pF, 50 V, +/- 5%, C0G/NP0, 0603	06035A560JAT2A	AVX
1	C23	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0603	C0603X102K5RACTU	KEMET
1	C24	CAP, CERM, 330 pF, 50 V, +/- 5%, C0G/NP0, 0603	C0603C331J5GACTU	KEMET
1	D1	Bridge Rectifier Single Phase Standard 1 kV Through Hole GBU	GBU4M-E3/51	Vishay Semiconductor
1	D2	Diode Schottky 200 V 6 A ITO220AC	MBR6200F_T0_00001	Panjit
1	D3	Diode, Ultrafast, 600 V, 1 A, SMB	MURS160-13-F	Diodes Inc.
1	D4	Zener Diode 20 V 500 mW ±5% Surface Mount SOD-123	MMSZ4707T1G	Onsemi
2	D5, D6, D8	Diode Standard 200 V 200 mA Surface Mount SOT-23-3 (TO-236)	BAS20LT3G	On Semiconductor
1	F1	Fuse, 3.15 A, 250VAC/VDC, TH	39213150000	Littelfuse
2	H1, H2	Heat Sink, TO-220 Vertical	7173DG	Aavid
4	H3, H4, H5, H6	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	B&F Fastener Supply
4	H7, H8, H9, H10	Standoff, Hex, 0.5"L #4-40 Nylon	1902C	Keystone
1	J1	Header, 312mil, 3x1, Tin, TH	1-1318301-3	TE Connectivity
1	J2	Terminal Block, 5.08 mm, 2x1, TH	1715721	Phoenix Contact
1	L1	22 µH Semi-Shielded Drum Core, Wirewound Inductor 1.8 A 89mOhm Nonstandard	74404064220	Würth Electronics
1	L2	Coupled inductor, 1 mH, 2 A, 0.045 ohm, TH	744821201	Würth Elektronik
1	L3	1 µH Unshielded Drum Core, Wirewound Inductor 7.5 A 10mOhm Max Radial, Vertical Cylinder (Open)	744772010	Würth Electronics
2	MP1, MP2	Mounting Kit For TO-220 Heat Sinks	4880SG	Aavid Thermalloy
1	Q1	MOSFET, N-CH, 700 V, 13 A, TO-220AB	IPP65R190C7	Infineon Technologies
1	R1	RES, 511 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	ERJ-6ENF5113V	Panasonic

Table 4-1. UCC28750EVM-001 Bill of Materials (continued)

QTY	DES	DESCRIPTION	PART NUMBER	MANUFACTURER
3	R2, R3, R4	RES, 2.00 M, 1%, 0.25 W, 1206	RC1206FR-072ML	Yageo America
1	R5	100 Ohms \pm 0.1% 0.2W, 1/5W Chip Resistor 0805 (2012 Metric) Anti-Sulfur, Automotive AEC-Q200, Moisture Resistant	TNPW0805100RBYEN	Vishay
1	R6	RES, 22.1, 1%, 0.5 W, 1210	RC1210FR-0722R1L	Yageo
1	R7	RES, 0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603ZT0R00	Stackpole Electronics Inc
1	R8	RES, 51.0, 1%, 0.25 W, 1206	RC1206FR-0751RL	Yageo America
1	R9	RES, 22.0, 1%, 0.1 W, 0603	RC0603FR-0722RL	Yageo
1	R10	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	RMCF0603FT10K0	Stackpole Electronics Inc
2	R11, R19	RES, 10.0 k, 1%, 0.25 W, 1206	RC1206FR-0710KL	Yageo America
1	R12	RES, 2.49 k, 1%, 0.1 W, 0603	RC0603FR-072K49L	Yageo
1	R13	RES, 1.00 k, 0.1%, 0.1 W, 0603	RT0603BRD071KL	Yageo America
1	R14	RES, 86.6 k, 0.1%, 0.125 W, 0805	RT0805BRD0786K6L	Yageo America
1	R15	RES, 133 k, 1%, 0.25 W, 1206	RC1206FR-07133KL	Yageo America
2	R16, R17	RES, 0.56, 1%, 0.25 W, 1206	ERJ-8RQFR56V	Panasonic
1	R18	RES, 220, 1%, 0.1 W, 0603	RC0603FR-07220RL	Yageo
1	R21	RES, 20.5 k, 1%, 0.125 W, AEC-Q200 Grade 0, 0805	ERJ-6ENF2052V	Panasonic
1	T1	CCM Flyback Transformer for UCC28750EVM-071	RLTI-1450	Renco Electronics
13	TP1, TP2, TP3, TP4, TP5, TP7, TP8, TP10, TP12, TP13, TP15, TP16, TP17	Test Point, Compact, Red, TH	5005	Keystone Electronics
3	TP6, TP9, TP18	Test Point, Compact, Black, TH	5006	Keystone Electronics
2	TP11, TP14	Test Point, Compact, White, TH	5007	Keystone Electronics
1	U1	Optocoupler, 3.75 kV, 80-160% CTR, SMT	TCMT1107	Vishay-Semiconductor
1	U2	Adjustable Precision Shunt Regulator, 34 ppm / degC, 100 mA, -40 to 85 degC, 3-pin SOT-23 (DBZ), Green (RoHS & no Sb/Br)	TL431AIDBZR	Texas Instruments
1	U3	Continuous Conduction Mode (CCM) Secondary Side Regulated (SSR) Current-Mode Offline Flyback Controller	UCC287502DBV	Texas Instruments

5 Additional Information

5.1 Trademarks

All trademarks are the property of their respective owners.

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 semiconductor 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.

WARNING

Evaluation Kits 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 shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

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/lstds/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。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

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。

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ンスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 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/lstds/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。 <https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html>

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.

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- 4 *EVM Use Restrictions and Warnings:*
 - 4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
 - 4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
 - 4.3 *Safety-Related Warnings and Restrictions:*
 - 4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
 - 4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
 - 4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.
 5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.
 6. *Disclaimers:*
 - 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, INDEMNITY 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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