Using the UCC25630-1EVM-291

User's Guide

Literature Number: SLUUBQ8B
August 2017–Revised January 2017

Contents

List of Figures

List of Tables

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

WARNING

Always follow TI's setup and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure 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.

Failure to follow warnings and instructions may 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 suitable qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety
   1. Keep work area clean and orderly.
   2. Qualified observer(s) must be present anytime circuits are energized.
   3. Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   4. 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.
   5. Use stable and nonconductive work surface.
   6. 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 may have fully accessible and active high voltages.
   1. De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   2. 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.
   3. After EVM readiness is complete, energize the EVM as intended.

   WARNING: WHILE THE EVM IS ENERGIZED, NEVER TOUCH THE EVM OR ITS ELECTRICAL CIRCUITS AS THEY COULD BE AT HIGH VOLTAGES CAPABLE OF CAUSING ELECTRICAL SHOCK HAZARD.
3. Personal Safety
   1. 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.

Using the UCC25630-1EVM-291

1 Introduction

This EVM, UCC25630-1EVM-291, is used to help evaluate the UCC256301 LLC control device in digital TV SMPS, AC-DC power adapter, LED lighting, etc. applications and then to aid their design. The EVM is a standalone LLC resonant half-bridge DC-DC power converter. The EVM, UCC25630-1EVM-291, can be used as it is delivered without additional work to evaluate an LLC resonant half-bridge DC-DC converter. This user's guide provides basic evaluation instruction from a viewpoint of system operation in standalone LLC resonant half-bridge DC-DC power converter.

2 Description

UCC25630-1EVM-291 is an EVM for an LLC resonant half-bridge DC-DC power converter with LLC controller UCC256301. UCC25630-1EVM-291 accepts DC line input from 340 VDC to 410 VDC, AC input voltage from 85 VAC to 264 VAC, and a nominal output of 12 VDC with a full-load output power of 120 W, or a full output current of 10 A.

NOTE: This EVM does not have an input fuse, and relies on an input current limit from its input voltage source.

2.1 Typical Applications

- Digital TV SMPS
- AC-DC Power Adapters
- Enterprise Server Applications
- LED Lighting Applications

2.2 Features

- Hybrid Hysteretic Controlled LLC Resonant Half-Bridge DC-DC Power Conversion
- DC Line Input from 340 VDC to 410 VDC
- AC Input Voltage from 85 VDC to 264 VAC
- Regulated 12-VDC Output, from No-Load to Full-Load
- Full-Load Power of 120 W, or Full-Load Current of 10 A
- High Efficiency
- Optimized Low Power Features Enable Extremely Low Standby Power
- Advanced Burst Mode with Adaptive Threshold
- Improved Capacitive Region Avoidance Scheme
- Adaptive Dead-Time
- X-Capacitor Discharge
- Over Temperature, Output Over Voltage, and Three Level Over Current Protections
- Test Points to Facilitate Device and Topology Evaluation

2.3 Using the EVM with UCC256302

To use this EVM with UCC256302:

- Replace U1 with UCC256302
- Remove D1, D2
- Connect TP10 to TP5

2.4 Using the EVM with UCC256303

UCC25630-1EVM-291 is designed for UCC256301. With a slightly modification, this EVM can be used for UCC256303. To use this EVM with UCC256303:

- Replace U1 with UCC256303
- Remove R11, D4
- Connect pin1 (HV) of U1 to PGND
- Connect external bias (11.25V - 26V) to TP21

2.5 Using the EVM with UCC256304

To use this EVM with UCC256304:

- Replace U1 with UCC256304
- Change R4 to 44.2 kΩ

3 Performance Specifications

Table 1. UCC25630-1EVM-291 Specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNITS
	INPUT CHARACTERISTICS					
	DC voltage range		340	390	410	VDC
	AC voltage range		85		264	VAC
	AC voltage frequency		47		63	Hz
	Input DC UVLO On			320		VDC
	Input DC UVLO Off			140		VDC
	Input DC current	Input = 340 VDC, full load = 10 A		0.383		A
	Input DC current	Input = 390 VDC, full load = 10 A		0.331		A
	Input DC current	Input = 410 VDC, full load = 10 A		0.315		A
	OUTPUT CHARACTERISTICS					
V_{OUT}	Output voltage	No load to full load = 10 A		12		VDC
I_{OUT}	Output load current	340 to 410 VDC			10	A
	Output voltage ripple	390 VDC and full load = 10 A		130		mVpp
	SYSTEM CHARACTERISTICS					
	Switching frequency		53		160	kHz
	Peak efficiency	390 VDC, load = 8 A		92.9%		
	Operating temperature	Natural convection		25		ºC

Table 2. UCC25630-1EVM-291 Typical No Load and Standby Power

V_{IN} = 390 V		
INPUT POWER (mW)	**OUTPUT POWER (mW)**	**POWER LOSS (mW)**
39.7	0	39.7
163.7	103.0	60.6
295.0	201.2	93.8
421.7	299.0	122.7
548.0	401.6	146.4
674.0	498.6	175.4

4 UCC25630-1EVM-291 Schematic

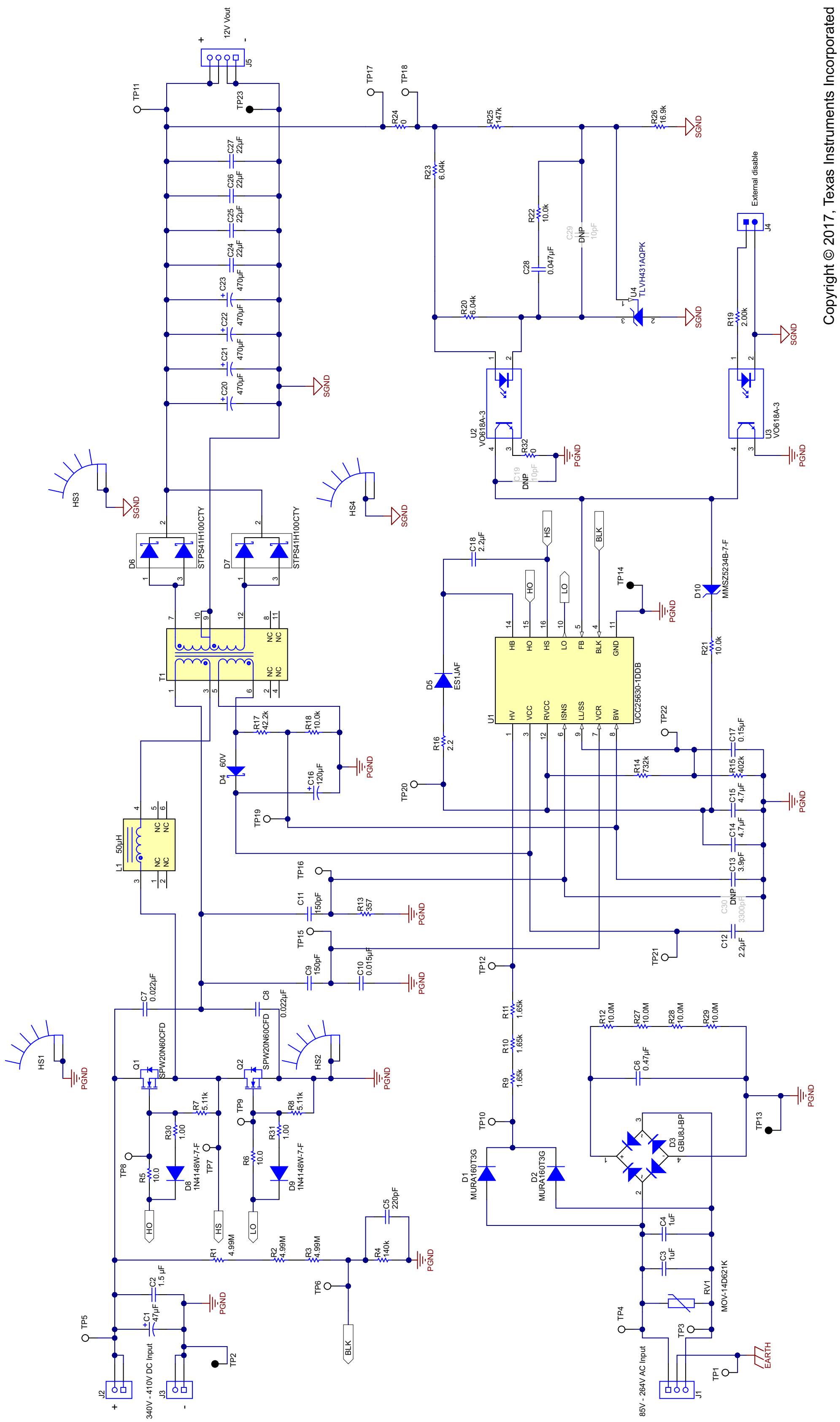

Figure 1. UCC25630-1EVM-291 Schematic

5 Test Setup

5.1 Test Equipment

DC Voltage Source: capable of 340 VDC to 410 VDC, adjustable, with minimum power rating 200 W, or current rating not less than 1 A, with current limit function. The DC voltage source to be used should meet IEC60950 reinforced insulation requirement.

AC Voltage Source: capable of single-phase output AC voltage 85 VAC to 264 VAC, 47 Hz to 63 Hz, adjustable with minimum power rating 100 W. The AC voltage source to be used should meet IEC60950 reinforced insulation requirement.

DC Digital Multimeter: One unit capable of 0-VDC to 450-VDC input range, four digit display preferred; and one unit capable of 0-VDC to 20-VDC input range, four digit display preferred.

Output Load: DC load capable of receiving 0 VDC to 20 VDC, 0 A to 15 A, and 0 W to 200 W or greater, with the capability to display things such as load current and load power.

Current Meter: DC, optional in case the load has no display, one unit, capable of 0 A to 15 A. If you want to measure standby power, the current meter needs to have a time averaging function.

Oscilloscope: capable of 500-MHz full bandwidth, digital or analog, if digital, 5 Gs/s or better.

Fan: 200-LFM to 400-LFM forced air cooling is recommended, but not required.

Recommended Wire Gauge: capable of 15 A, or better than #14 AWG, with the total length of wire less than 8 feet (4 feet input and 4 feet return).

5.2 Recommended Test Setup at No Load

Figure 2 shows the equipment setup for testing at no load. It is important to note that in this setup, current drawn by the voltage meter does not flow through the current meter.

Also, do not connect oscilloscope probes or any other sensing devices to the unit while measuring no-load power, as these can provide a path for common mode current to flow. This causes an error in the measurements.

During the no-load test, the current meter should be set to long-averaging mode and a few minutes should be allowed for the reading to be accurate. Additionally, an appropriate current scale factor should be used.

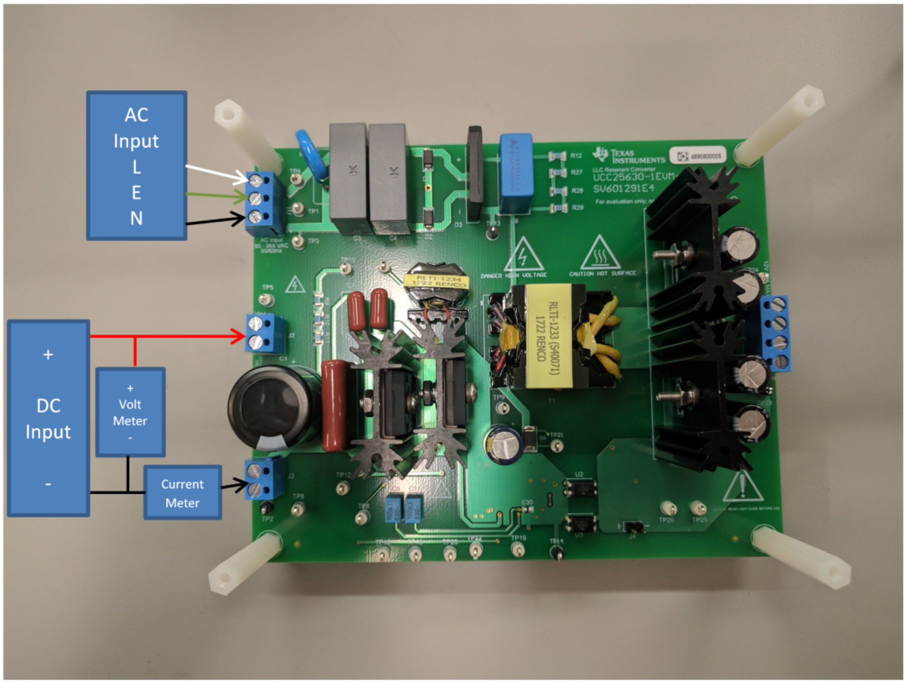

Figure 2. UCC25630-1EVM-291 Recommended Test Setup for No Load

5.3 Recommended Test Setup With Load

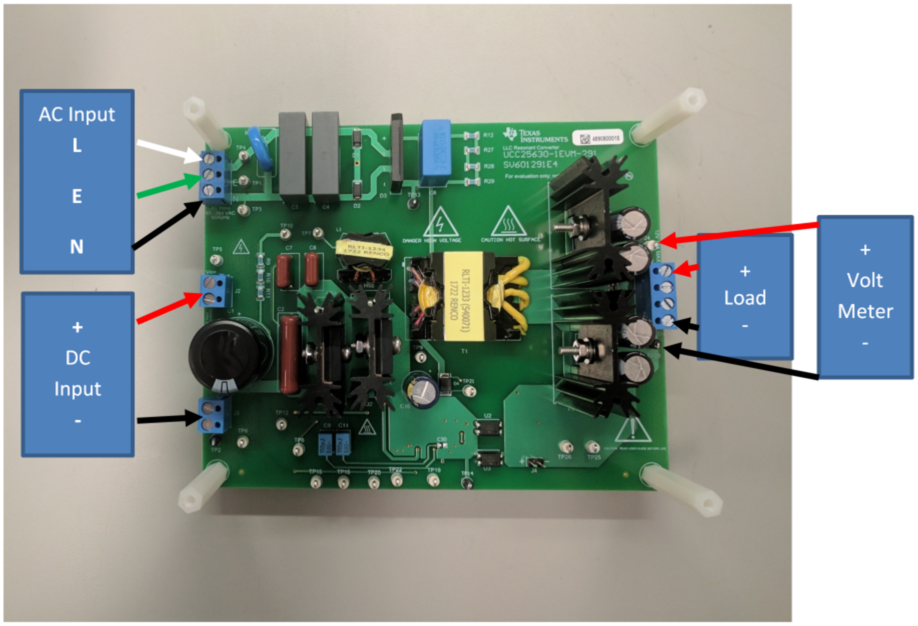

Figure 3. UCC25630-1EVM-291 Recommended Test Setup With Load

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

6 List of Test Points

Table 3. Test Points

TEST POINTS	NAME	DESCRIPTION
TP1	EARTH	AC earth
TP2	VIN_N	Input voltage return terminal
TP3	AC_N	AC neutral
TP4	AC_L	AC line
TP5	VIN_P	Input voltage positive terminal
TP6	BLK	Input voltage sensing
TP7	HS	Primary-side switch node, or the intersection of Q1 and Q2
TP8	HO	Primary-side high side MOSFET gate, Q1
TP9	LO	Primary-side low side MOSFET gate, Q2
TP10	AC_R	AC rectifier output
TP11	VOUT_P	Output voltage positive terminal
TP12	HV	High-voltage start pin
TP13	PGND	Primary-side ground
TP14	PGND	Primary-side ground
TP15	VCR	Resonant capacitor voltage sense
TP16	ISNS	Resonant current sense

Table 3. Test Points (continued)

TEST POINTS	NAME	DESCRIPTION
TP17	INJECT1	Small signal injection terminal
TP18	INJECT2	Small signal injection terminal
TP19	BW	Bias winding voltage sense
TP20	RVCC	Regulated 12-V supply
TP21	VCC	Supply input
TP22	LL/SS	Soft-start and light-load burst mode threshold
TP23	VOUT_N	Output voltage return terminal

7 List of Terminals

Table 4. Terminals

TERMINAL	NAME	DESCRIPTION
J1	AC Input	3-pin, AC power input, 85 V to 265 V
J2	VIN_P	Input voltage positive terminal
J3	VIN_N	Input voltage return terminal
J4	DISABLE	External disable terminal
J5	VOUT	Output voltage terminal, 4-pin

8 Test Procedure

1. Refer to Figure 3 for basic setup. The required equipment for this measurement is listed in Section 5.1.
2. Before making electrical connections, visually check the board to make sure there are no suspected spots of damage.
3. Keep the DC voltage source output off, connect it to J2 (+) and J3 (-). The DC voltage source should be isolated and meet the IEC60950 requirement. Set the DC output voltage within the range specified in Table 1, between 340 VDC and 410 VDC; set the DC source current limit to 1 A.

NOTE: The board has no fuse installed and relies on the external voltage source current limit to ensure circuit protection.

4. Connect an electronic load set to either constant current mode or constant resistance mode. The load current range is from 0 A to 10 A.
5. Keep the AC voltage source output off, connect it to J1 with AC_line to J1-1, AC_earth to J1-2, AC_neutral to J1-3. The AC voltage source should be isolated and meet the IEC60950 requirement. Set the AC output voltage in the range specified in Table 1, between 85 VAC and 264 VAC; set the AC source current limit to 200 mA.
6. If the load does not have a current or a power display, a current meter needs to be inserted between the load and the board.
7. Connect a voltage meter across the load and set the meter's scale to 20 VDC.
8. Turn on the AC voltage source output.
9. Turn on the DC voltage source output. Then the measurements can be made.

8.1 Equipment Shutdown

1. Shut down AC voltage source.
2. Shut down DC voltage source.
3. Shut down electronic load.

9 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 15 present typical performance curves for UCC25630-1EVM-291.

9.1 Efficiency

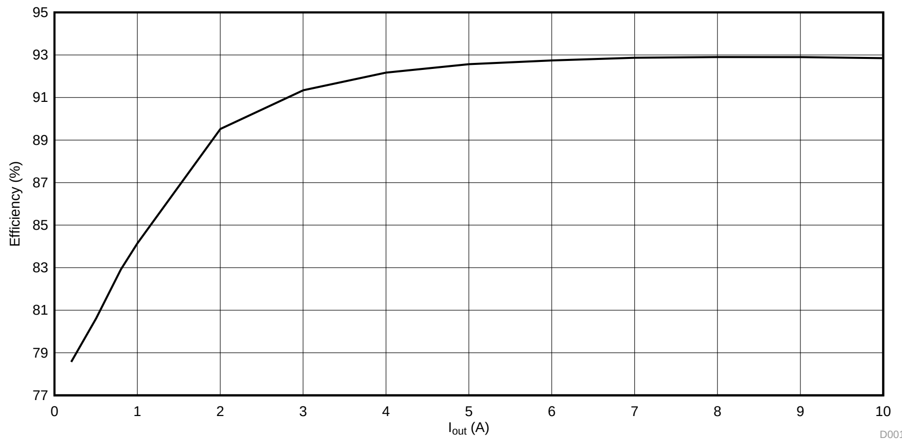

Figure 4. UCC25630-1EVM-291 Efficiency

9.2 Load Regulation

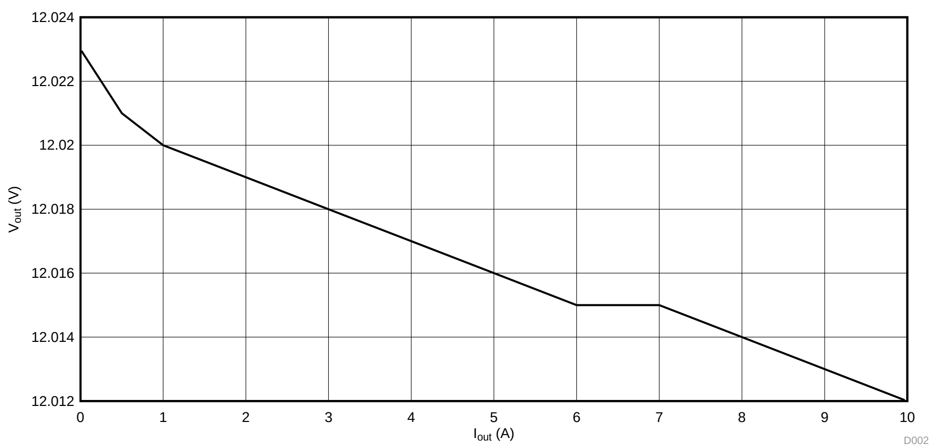

Figure 5. UCC25630-1EVM-291 Load Regulation

9.3 Output Turn On

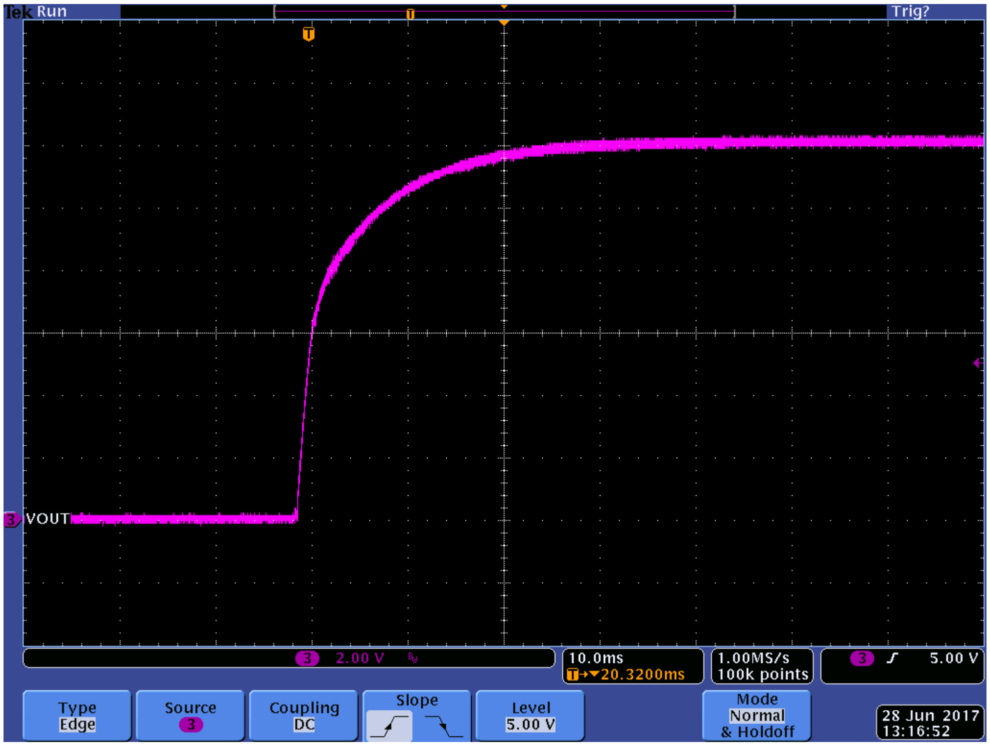

Figure 6. Output Turn On at 390 VDC with Full Load (10 A)

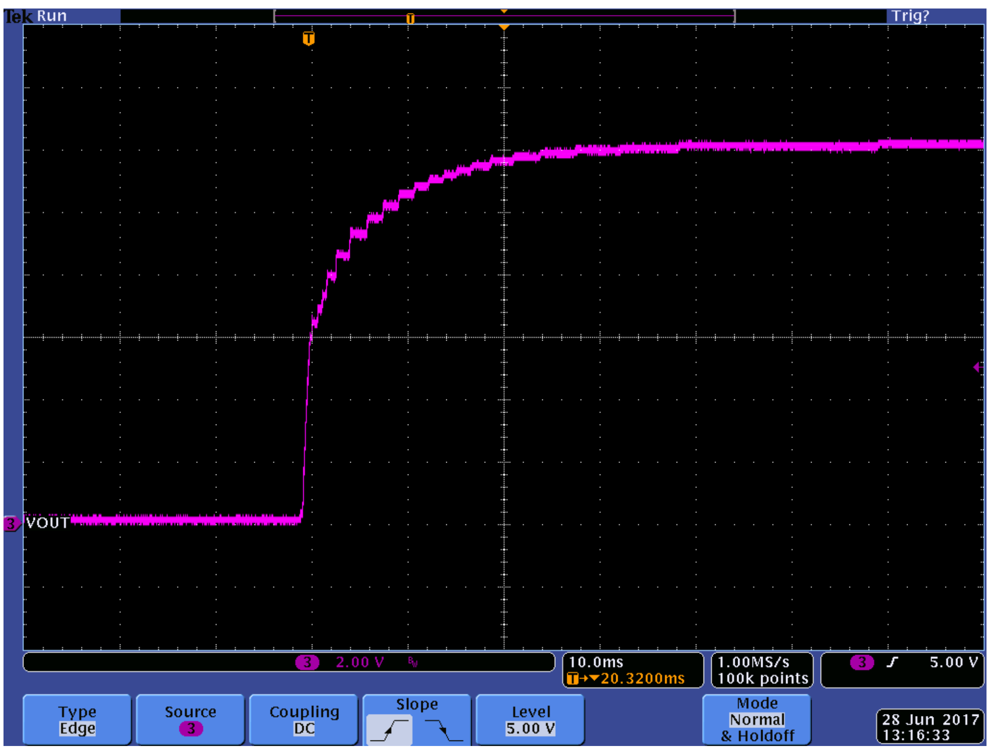

Figure 7. Output Turn On at 390 VDC with No Load

9.4 Load Transient

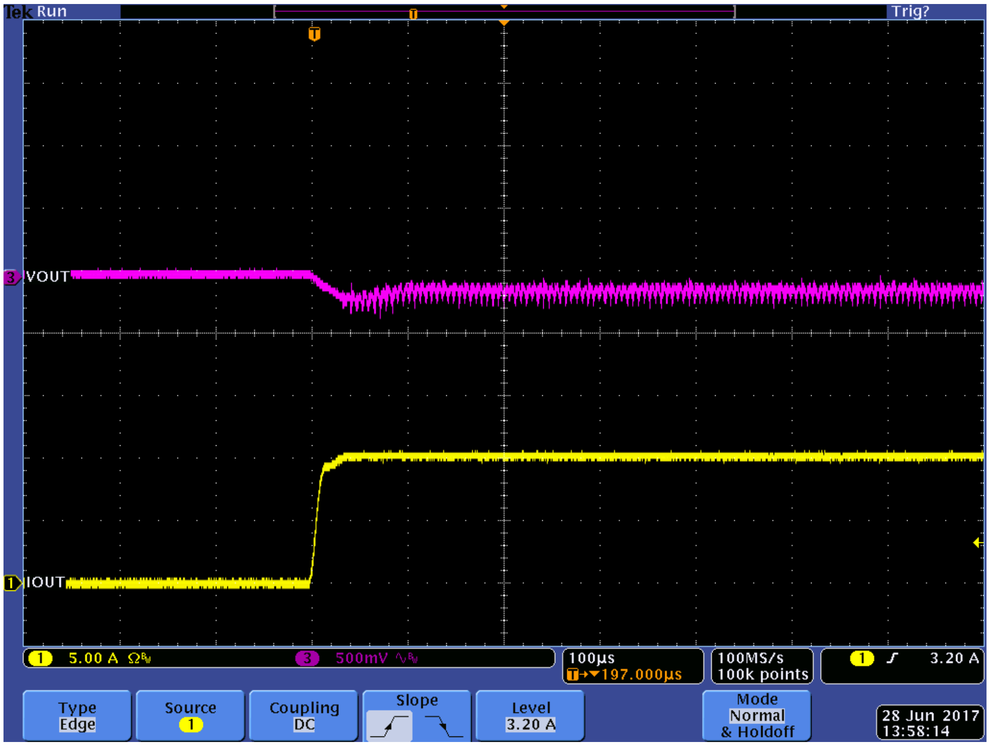

Figure 8. No Load (0 A) to Full Load (10 A) Transient (Ch1 = I_{out} ; Ch3 = V_{out})

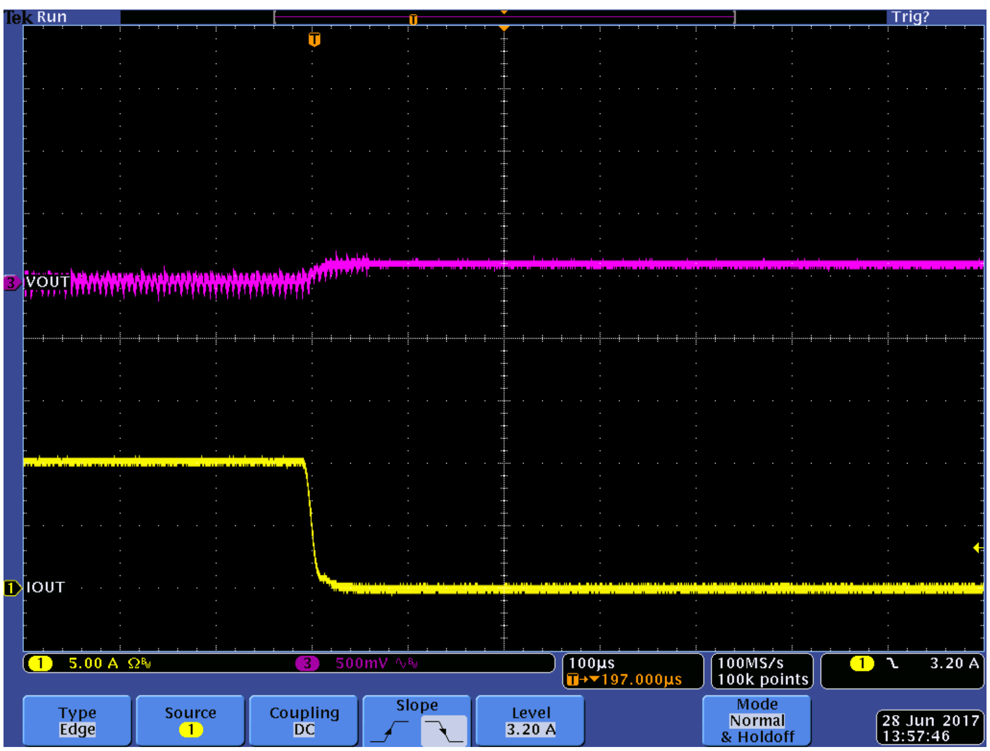

Figure 9. Full Load (10 A) to No Load (0 A) Transient (Ch1 = I_{out} ; Ch3 = V_{out})

9.5 Output Voltage Ripple

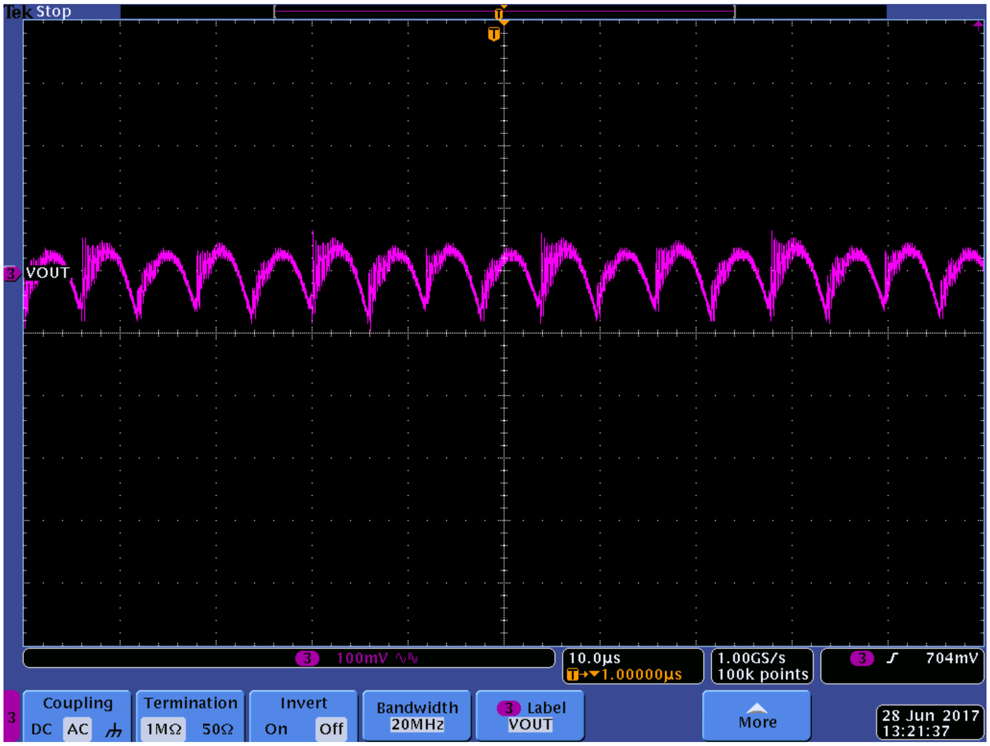

Figure 10. Output Voltage Ripple at V_{in} = 390-V and 10-A Load

9.6 Burst Mode at Light Load

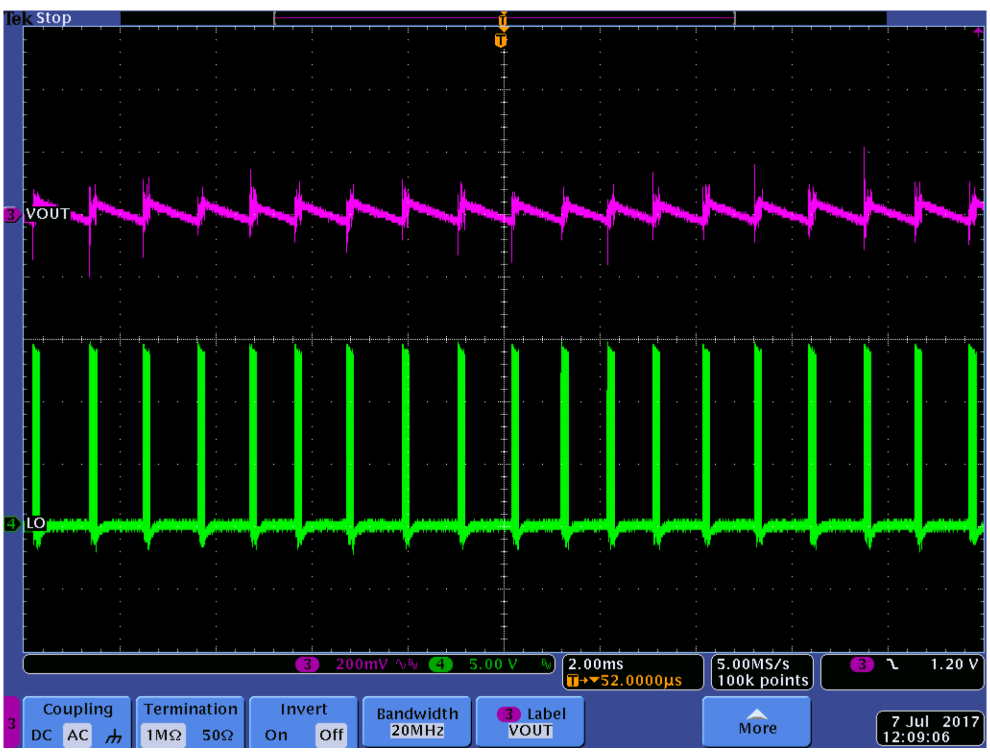

Figure 11. Burst Mode at V_{in} = 390-V and 100-mA Load (Ch3 = V_{out} ; Ch4 = LO)

9.7 Voltage on Resonant Capacitor

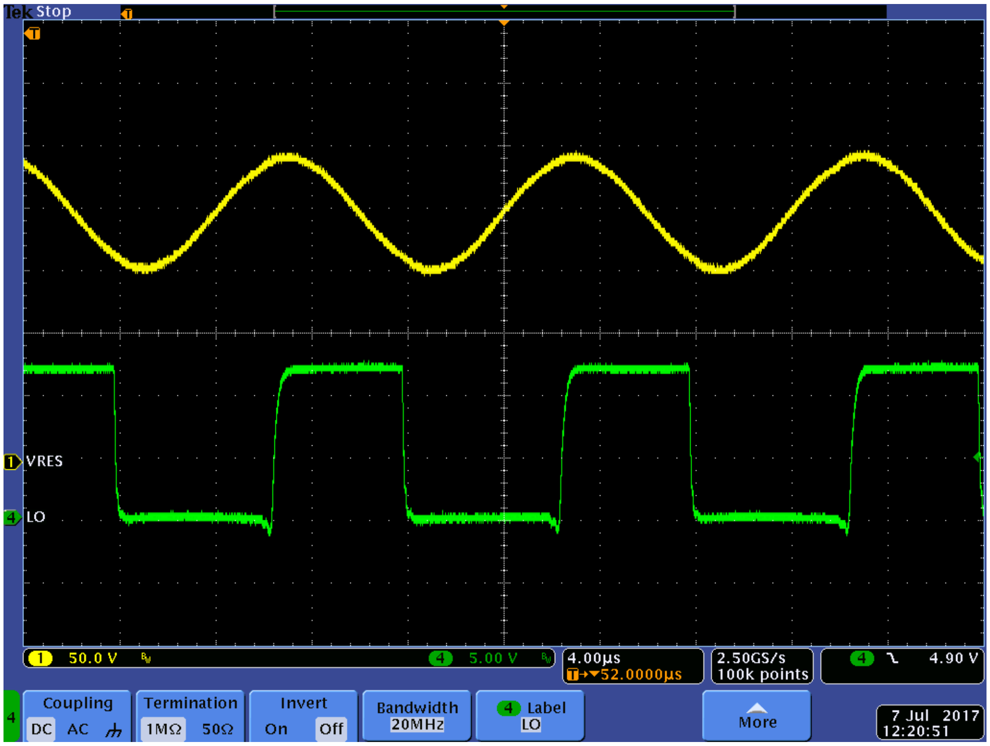

Figure 12. Voltage on Resonant Capacitor (V_{in} = 390-V and 10-A Load, Ch1 = V_{RES} ; Ch4 = LO)

9.8 X-Cap Discharge

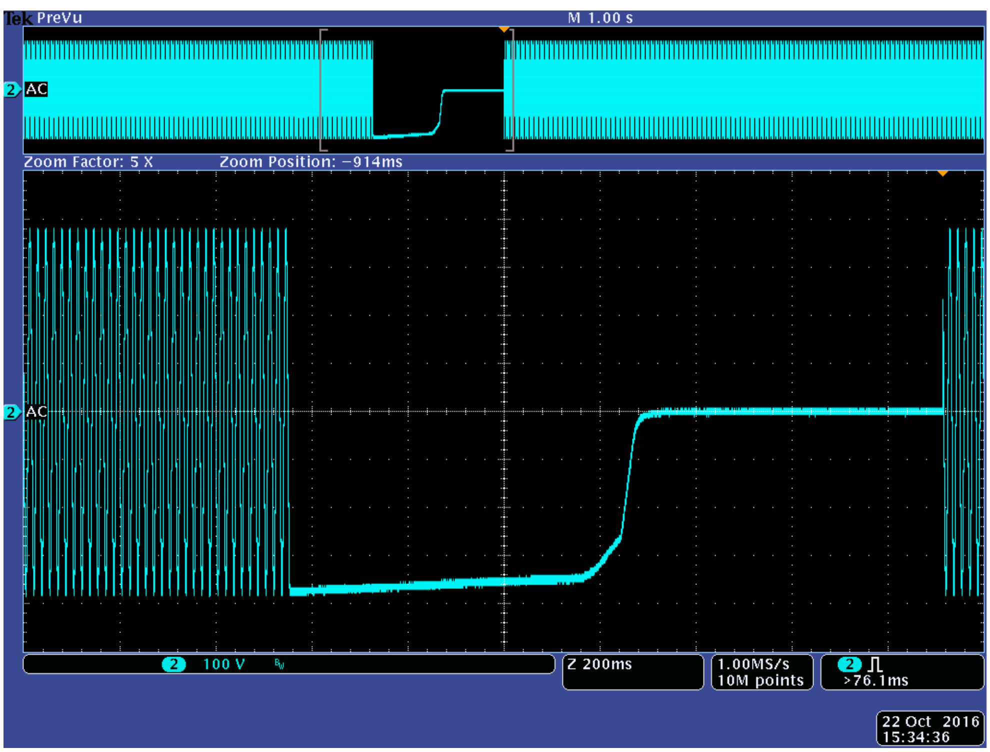

Figure 13. X-Cap Discharge

(Test condition: V_{AC} = 264 V_{RMS}, disconnected AC randomly, discharge time from 373 VAC to below 30 V: 700 ms)

9.9 Bode Plot

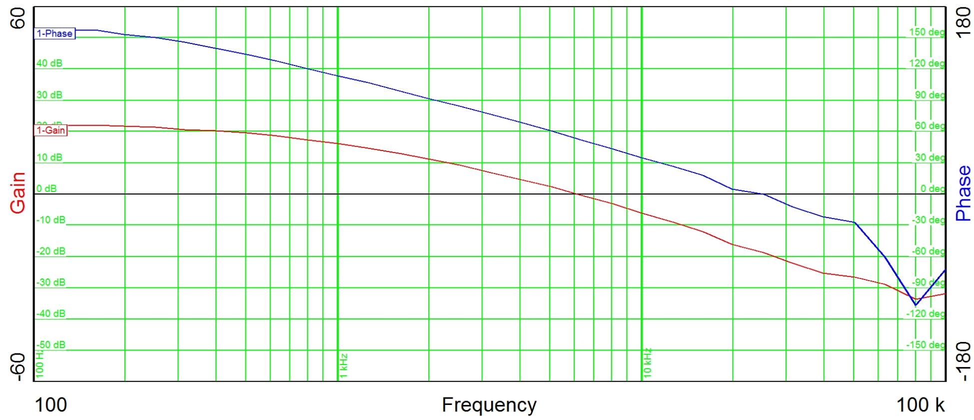

Figure 14. Bode Plot at V_{in} = 390 V and 10 A Load

9.10 Switching Frequency vs. Load

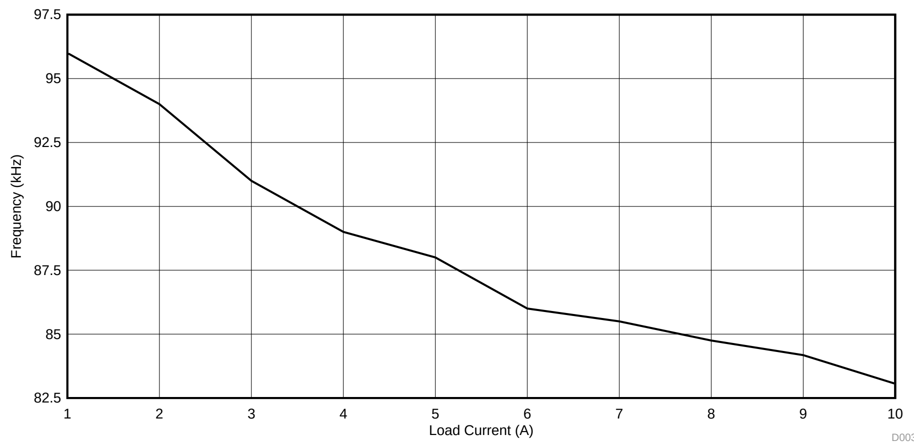

Figure 15. Switching Frequency vs. Load (V_{in} = 390 V)

10 EVM Assembly Drawing and PCB Layout

Figure 16 through Figure 19 show the design of the UCC25630-1EVM-291 printed circuit board. PCB dimensions: L x W = 5.9 x 4.8 in, PCB material: FR4 or compatible, two layers and 2 oz copper on each layer.

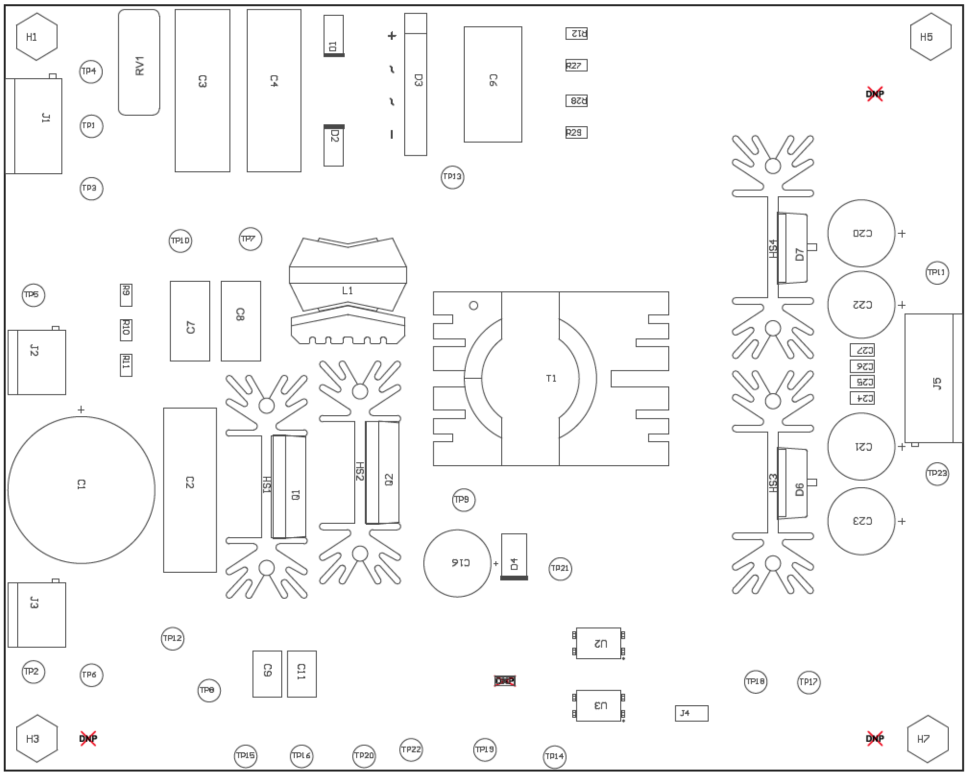

Figure 16. UCC25630-1EVM-291 Top Layer Assembly Drawing (Top View)

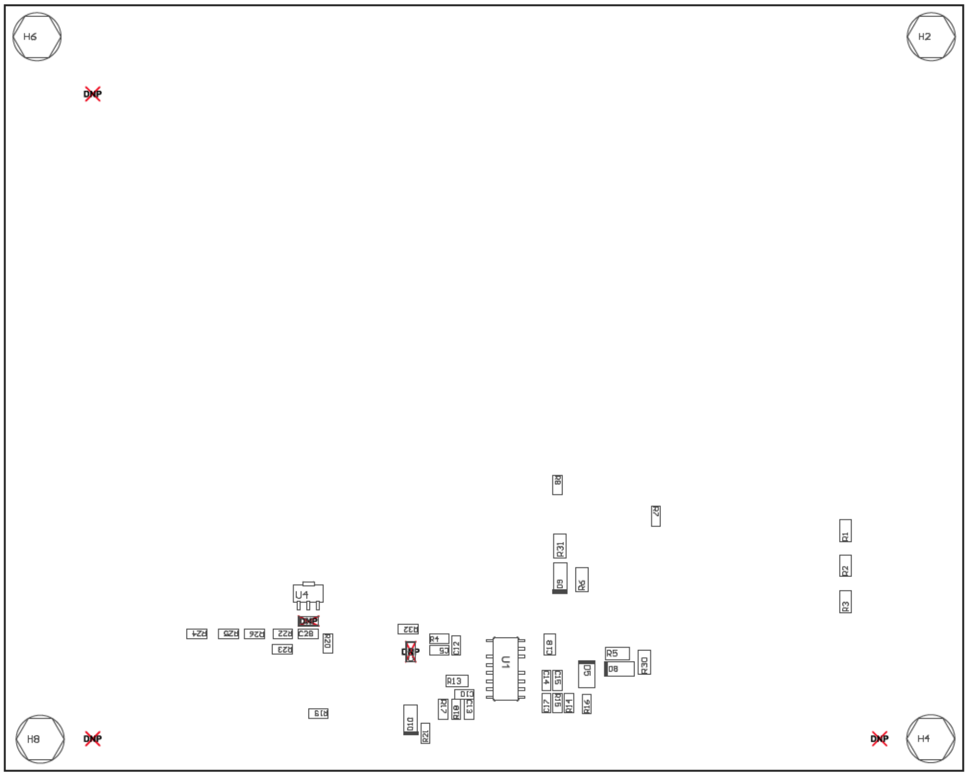

Figure 17. UCC25630-1EVM-291 Bottom Layer Assembly Drawing (Bottom View)

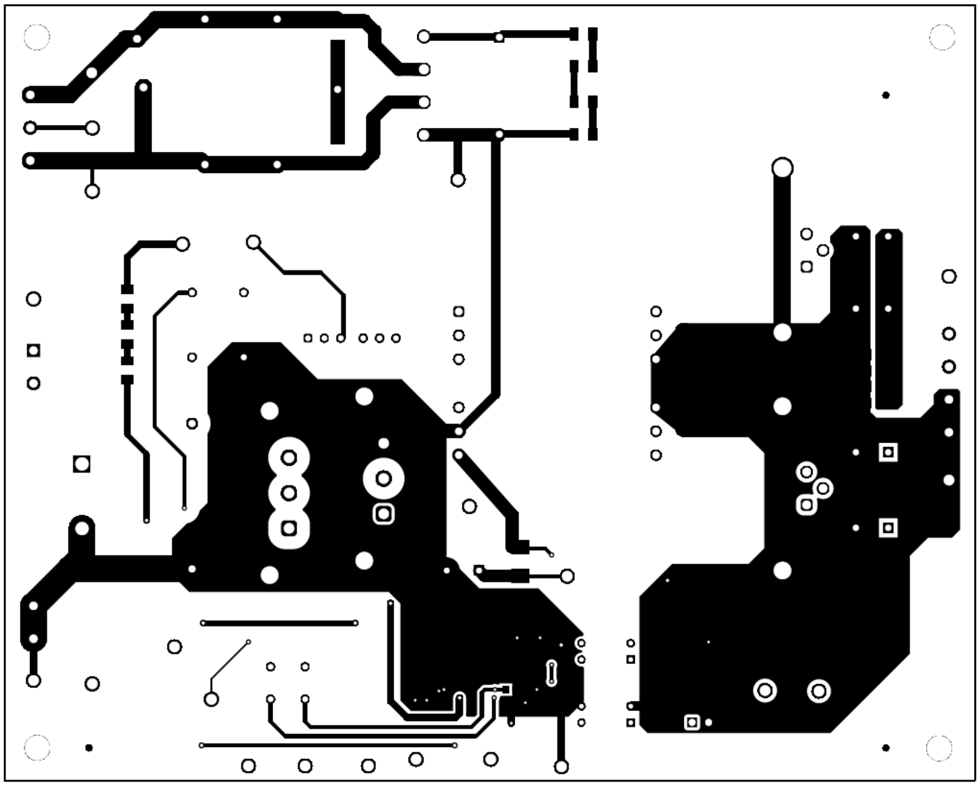

Figure 18. UCC25630-1EVM-291 Top Copper (Top View)

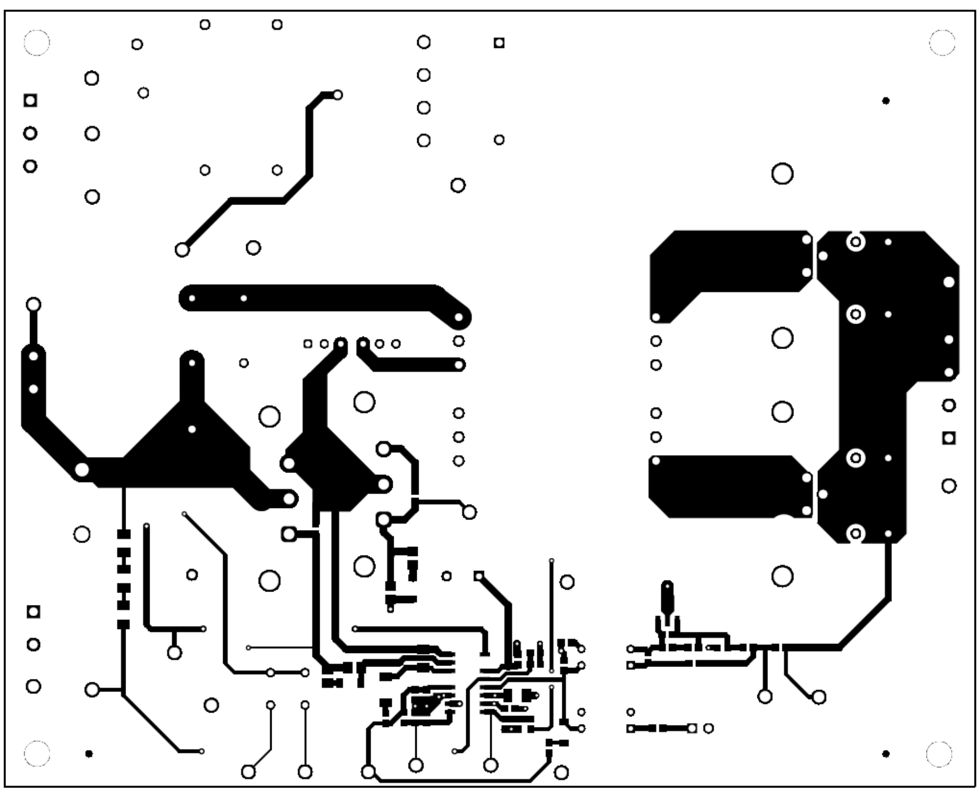

Figure 19. UCC25630-1EVM-291 Bottom Copper (Top View)

11 List of Materials

Table 5. UCC25630-1EVM-291 List of Materials

DES	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
PCB1	1	Printed Circuit Board	SV601291	Any
C1	1	Capacitor, aluminum, 47 µF, 450 V, ±20%, 2.82 ohm, TH	B43501A5476M000	TDK
C2	1	Capacitor, film, 1.5uF, 450V, ±10%, TH	ECQ-E2W155KH	Panasonic
C3, C4	2	Capacitor, film, 1uF, 275V, ±20%, TH	R46KN410000P0M	Kemet
C5	1	Capacitor, ceramic, 220 pF, 50 V, ±10%, X7R, 0603	GRM188R71H221KA01D	MuRata
C6	1	Capacitor, film, 0.47 µF, 630 V, ±10%, TH	B32922C3474K	TDK
C7, C8	2	Capacitor, film, 0.022 µF, 630 V, ±5%, TH	ECWF6223JL	Panasonic
C9, C11	2	Capacitor, film, 150 pF, 630 V, ±5%, TH	PFR5151J630J11L4BULK	Kemet
C10	1	Capacitor, ceramic, 0.015 µF, 25 V, ±5%, C0G/NP0, 0603	C0603C153J3GACTU	Kemet
C12	1	Capacitor, ceramic, 2.2 µF, 35 V, ±10%, X5R, 0603	GRM188R6YA225KA12D	MuRata
C13	1	Capacitor, ceramic, 3.9 pF, 50 V, ±6%, C0G/NP0, 0603	06035A3R9CAT2A	AVX
C14, C15	2	Capacitor, ceramic, 4.7 µF, 16 V, ±10%, X5R, 0603	GRM188R61C475KAAJ	MuRata
C16	1	Capacitor, aluminum, 120 µF, 63 V, ± 20%, 0.194 ohm, AEC-Q200 Grade 2, TH	EEU-FC1J121	Panasonic
C17	1	Capacitor, ceramic, 0.15 µF, 16 V, ±20%, Y5V, 0603	C0603C154Z4VACTU	Kemet
C18	1	Capacitor, ceramic, 2.2 µF, 16 V, ±10%, X7R, 1206	C1206C225K4RACTU	Kemet
C19	0	Capacitor, ceramic, 10 pF, 50 V, ±5%, C0G/NP0, 0603	06035A100JAT2A	AVX
C20, C21, C22, C23	4	Capacitor, aluminum, 470 µF, 35 V, ±20%, TH	35ZL470MEFC10X20	Rubycon
C24, C25, C26, C27	4	Capacitor, ceramic, 22 µF, 35 V, ± 20%, X5R, 0805	C2012X5R1V226M125AC	TDK
C28	1	Capacitor, ceramic, 0.047 µF, 16 V, ±10%, X7R, 0603	GRM188R71C473KA01D	MuRata
C29	0	Capacitor, ceramic, 10 pF, 50 V, ±5%, C0G/NP0, 0603	06035A100JAT2A	AVX
C30	0	Capacitor, ceramic, 3300 pF, 50 V, ±5%, C0G/NP0, 0603	GRM1885C1H332JA01D	MuRata
D1, D2	2	Diode, Ultrafast, 600 V, 1 A, SMA	MURA160T3G	ON Semiconductor
D3	1	Diode, Switching-Bridge, 420 V, 8 A, TH	GBU8J-BP	Micro Commercial Components
D4	1	Diode, Schottky, 60 V, 1 A, AEC-Q101, SMB	STPS160UY	STMicroelectronics
D5	1	Diode, Ultrafast, 600 V, 1 A, AEC-Q101, SMAF	ES1JAF	Fairchild Semiconductor
D6, D7	2	Diode, Schottky, 100 V, 20 A, AEC-Q101, TH	STPS41H100CTY	STMicroelectronics
D8, D9	2	Diode, Ultrafast, 100 V, 0.15 A, SOD-123	1N4148W-7-F	Diodes Inc.
D10	1	Diode, Zener, 6.2 V, 500 mW, SOD-123	MMSZ5234B-7-F	Diodes Inc.
H1, H3, H5, H7	4	Hex standoff 1-1/2" L #6-32 nylon	4824	Keystone
H2, H4, H6, H8	4	Hex standoff 0.5"L #6-32 nylon	1903C	Keystone
H9, H11	2	TO-220 mounting kit	4880SG	Aavid Thermalloy
H10, H12	2	TO-247 mounting kit	4880SG	Aavid Thermalloy
H13, H14	2	Large thermal pad to substitute for the smaller one in the TO-247 Mounting Kit	SP900S-0.009-00-104	Bergquist
HS1, HS2, HS3, HS4	4	Heatsink TO-220 w/pins 1.5" tall	531102B02500G	Aavid
J1	1	Terminal block, 5.08 mm, 3x1, brass, TH	ED120/3DS	On-Shore Technology

Table 5. UCC25630-1EVM-291 List of Materials (continued)

DES	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
J2, J3	2	Terminal block, 5.08 mm, 2x1, brass, TH	ED120/2DS	On-Shore Technology
J4	1	Header, 100 mil, 2 x 1, tin, TH	PEC02SAAN	Sullins Connector Solutions
J5	1	Terminal block, 5.08 mm, 4x1, brass, TH	ED120/4DS	On-Shore Technology
L1	1	Inductor, 50 µH, 0.023 Ω, TH	RLTI-1234	Renco Electronics
Q1, Q2	2	MOSFET, N-channel, 650 V, 20.7 A, TO-247	SPW20N60CFD	Infineon Technologies
R1, R2, R3	3	Resistor, 4.99 MΩ, 1%, 0.25 W, 1206	CRCW12064M99FKEA	Vishay-Dale
R4	1	Resistor, 140 kΩ, 1%, 0.1 W, 0603	CRCW0603140KFKEA	Vishay-Dale
R5, R6	2	Resistor, 10.0 Ω, 1%, 0.125 W, 0805	CRCW080510R0FKEA	Vishay-Dale
R7, R8	2	Resistor, 5.11 kΩ, 1%, 0.1W, 0603	CRCW06035K11FKEA	Vishay-Dale
R9, R10, R11	3	Resistor, 1.65 kΩ, 1%, 0.25 W, 1206	CRCW12061K65FKEA	Vishay-Dale
R12, R27, R28, R29	4	Resistor, 10.0 MΩ, 1%, 0.25 W, 1206	CRCW120610M0FKEA	Vishay-Dale
R13	1	Resistor, 357 Ω, 1%, 0.25 W, 1206	CRCW1206357RFKEA	Vishay-Dale
R14	1	Resistor, 732 kΩ, 1%, 0.1 W, 0603	CRCW0603732KFKEA	Vishay-Dale
R15	1	Resistor, 402 kΩ, 1%, 0.1 W, 0603	CRCW0603402KFKEA	Vishay-Dale
R16	1	Resistor, 2.2 Ω, 5%, 0.1 W, 0603	CRCW06032R20JNEA	Vishay-Dale
R17	1	Resistor, 42.2 kΩ, 1%, 0.1 W, 0603	CRCW060342K2FKEA	Vishay-Dale
R18, R21, R22	3	Resistor, 10.0 kΩ, 1%, 0.1 W, 0603	CRCW060310K0FKEA	Vishay-Dale
R19	1	Resistor, 2.00 kΩ, 1%, 0.1 W, 0603	CRCW06032K00FKEA	Vishay-Dale
R20, R23	2	Resistor, 6.04 kΩ, 1%, 0.1 W, 0603	CRCW06036K04FKEA	Vishay-Dale
R24, R32	2	Resistor, 0 Ω, 5%, 0.1 W, 0603	CRCW06030000Z0EA	Vishay-Dale
R25	1	Resistor, 147 kΩ, 1%, 0.1 W, 0603	CRCW0603147KFKEA	Vishay-Dale
R26	1	Resistor, 16.9 kΩ, 1%, 0.1 W, 0603	CRCW060316K9FKEA	Vishay-Dale
R30, R31	2	Resistor, 1.00 Ω, 1%, 0.125 W, 0805	CRCW08051R00FKEA	Vishay-Dale
RV1	1	Varistor 558 V 4.5KA, TH	MOV-14D621K	Bourns
T1	1	Transformer, 840 µH, TH	RLTI-1233	Renco Electronics

Table 5. UCC25630-1EVM-291 List of Materials (continued)

DES	QTY	DESCRIPTION	PART NUMBER	MANUFACTURER
TP1, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22	19	Test point, multipurpose, white, TH	5012	Keystone
TP2, TP13, TP14, TP23	4	Test point, multipurpose, black, TH	5011	Keystone
U1	1	Enhanced LLC Resonant Controller with Driver, DDB0014A	UCC256301DDB	Texas Instruments
U2, U3	2	Optocoupler, 5.3 kV, 50-600% CTR, TH	VO618A-3	Vishay-Semiconductor
U4	1	Low-Voltage Adjustable Precision Shunt Regulator, 80 mA, -40 to 125 degC, 3-pin SOT-89 (PK), Green (RoHS & no Sb/Br)	TLVH431AQPK	Texas Instruments
FID1, FID2, FID3, FID4, FID5, FID6	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A

Revision History

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

Changes from A Revision (September 2017) to B Revision	Page
• Added Using the EVM with UCC256302 section 2.3	6

Changes from Original (August 2017) to A Revision	Page
• Added Using the EVM with UCC256303 section 2.4	6
• Added Using the EVM with UCC256304 section 2.5	6

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

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